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WILTRON

MODEL 350 PHASE METER

INSTRUCTION MANUAL

WILTRON

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WARRANTY

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SECTION I

GENERAL INFORMATION

1-1. GENERAL DESCRIPTION

The WILTRON Model 350 Phase Meter (Figure 1-1) is a precision, solid-state instrument used to measure the phase angle difference between a reference signal and a test signal having the same frequency. The measured phase angle is read directly in degrees on a precision 4" zero center meter. The phase meter can be connected to automated data handling equipment by means of an analog output connector, which provides a dc voltage directly proportional to the measured angle.

The phase meter accepts single-ended inputs within the frequency range of 10Hz to 2MHz with either input having an rms input level value from 1mV to 400V. The phase angle can be measured in either of two switch selected ranges centered about 0° or 180°.

The instrument is self-contained, and operates from a power source of 115/230V ac, 50 to 400Hz. The unit is housed in a chassis 7" high, 19" wide, and 15" deep, suitable for bench use or mounting in a 19" wide rack. Weight of the unit is 20 pounds. Shipping weight is 30 pounds.

1-2. MEASUREMENT TECHNIQUE

The two input signals whose phase angle difference is to be measured are shaped by separate, identical four-stage limiter amplifiers preceded by field effect transistor source followers. The two shaped signals are applied to separate identical Schmitt trigger stages, each of which generates a negative pulse at the exact time its input signal crosses the zero axis from positive to negative. These successive pulses turn on and off a bi-stable multivibrator, the average dc component of which is proportional to the time difference between successive zero axis crossings of the two input signals, and therefore proportional to the phase angle.

The output waveform is smoothed (filtered) to obtain the average dc component, which is applied to the phase meter. The dc voltage, the analog of the phase angle measurement, varies between ±1.80 volts.

1-3. SPECIFICATIONS

Performance specifications for the phase meter are listed in Table 1-1. The performance specifications are met over a temperature range of 0° to 50°C after the internal temperature of the instrument has stabilized (at least 30 minutes warm-up time).

Table 1-1. Specifications

FREQUENCY RANGE

10 Hz to 2 MHz with useful performance above and below these frequencies.

INPUT LEVELS (Both inputs)

1mV to 2 volts rms or 200mV to 400 volts rms, switch selectable. DC blocking provided up to 400 volts.

INPUT IMPEDANCE

1 megohm shunted by 26pF or, when used with Tektronix oscilloscope probes (Model P6006), 10 megohms and 8pF.

ACCURACY OF PHASE READING

Absolute accuracy = $\pm 0.05 \pm \frac{\phi}{180} \times 0.25°$

where ϕ is the angle being measured. With the 0° – 180° switch at 180°, the accuracy is ±0.1 +0.3F degrees where F is the test frequency in MHz.

NOTE

This accuracy applies over the frequency range 100 Hz to 20 kHz after standardization at 0° with input levels of 30mV rms on the low input range or 6 volts rms on the high input range. Frequency and signal level effects out of this range are shown in Table 3-2. The effects of waveform distortion are described in paragraph 3-6.

METER READOUT ACCURACY

Six ranges: ±5°, ±10°, ±18°, ±50°, ±100°, ±180°. Accuracy = ±2% full scale. The offset circuit permits all measurements to be made on the ±5° or ±10° range. Thus the meter accuracy error need not exceed ±0.2° at any phase angle.

METER OFFSET

0 to ±170° in 10° increments. Accuracy = ±0.5% of the offset.

ACCURACY OF 0 - 180° SWITCH

Accuracy = ±(0.1 + 0.3F)° where F is the test frequency in MHz. Note that waveform distortion can cause an apparent discrepancy in this figure.

RANGE OF PHASE MEASUREMENT

360° - (40F)° where F is in MHz -- e.g., when on the ±180° range at 100 kHz the phase measurement range is ±178°. Angles around 180° are measured with the 0° –180° switch at +180°.

Accuracy: Same as phase reading accuracy.

ZERO CONTROL

Permits setting an absolute zero to take into account at a fixed frequency little differences in the length of input test leads. Without adjusting the zero control, the instrument "zero" will maintain within ±0.5° from 100 Hz to 100 kHz.

RESPONSE TIME

Low Freq. Limit Switch Position	*Response Time
1 kHz	40 msec.
100 Hz	400 msec.
30 Hz	1.3 sec.
10 Hz	4 sec.

*Approximate for 180° change to 0.1° of final value.

SECTION II
INSTALLATION

2-1. INSTALLATION PLANNING

The phase meter may be rack-mounted or used on a cart or desk-top and adjacent to any other laboratory type equipment, provided the environment requirements specified in paragraph 1-3 are met. Rack mounting ears are supplied with the instrument only if specifically requested with order. Dimensions of the unit are shown in Figure 1-2.

The phase meter does not require forced cooling air. However, the sides, top and bottom of the instrument must not be obstructed from ambient air.

A standard three-pin power outlet must be available for connection of the power input cord which is captive at the rear of the instrument. See paragraph 1-1 for power requirements. The chassis is grounded by means of the three-wire power cord. No additional chassis grounding is required.

The standard instrument has the signal inputs and the analog of phase measurement (PHASE OUT connector) on the front panel. The phase meter can be supplied with optional rear panel signal inputs and optional rear panel PHASE OUT connector. If these options are ordered, all signal inputs and outputs can be connected at the rear panel with the corresponding front panel inputs used for testing or for measurements.

2-2. UNPACKING

The phase meter is shipped in a special packing case which should be saved if reshipment or storage of the unit is anticipated. As the phase meter is unpacked, exercise care to avoid damage to the finished surfaces. The phase meter weighs about 20 pounds, or about 30 pounds crated. All parts should be inspected for evidence of damage during shipment. If the unit is damaged, advise WILTRON and file a claim with the transfer company.

2-3. RECEIVING INSPECTION

The phase meter can be checked for proper operation by performing the performance verification procedure in Section V. If the phase meter does not operate properly, it is likely that internal damage has been incurred during shipment. Contact WILTRON Company.

2-4. INSTALLATION PROCEDURE

To rack-mount the phase meter, proceed as follows:

1. Install the rack-mounting ears on both sides of the chassis using the supplied hardware.

2. Secure the phase meter to the rack using four screws.

3. From the rear of the phase meter, check that the fuse is installed and intact. The correct fuse rating is 115/230V ac, 0.3 amp slo-blo.

4. Check that the voltage selector switch (115V or 230V) on the rear panel is in the correct position.

5. Set the power switch to the off (down position and connect the power cord to the power source. See instructions in paragraph 3-3 for signal input and output cable connections and impedance matching requirements for external equipment.

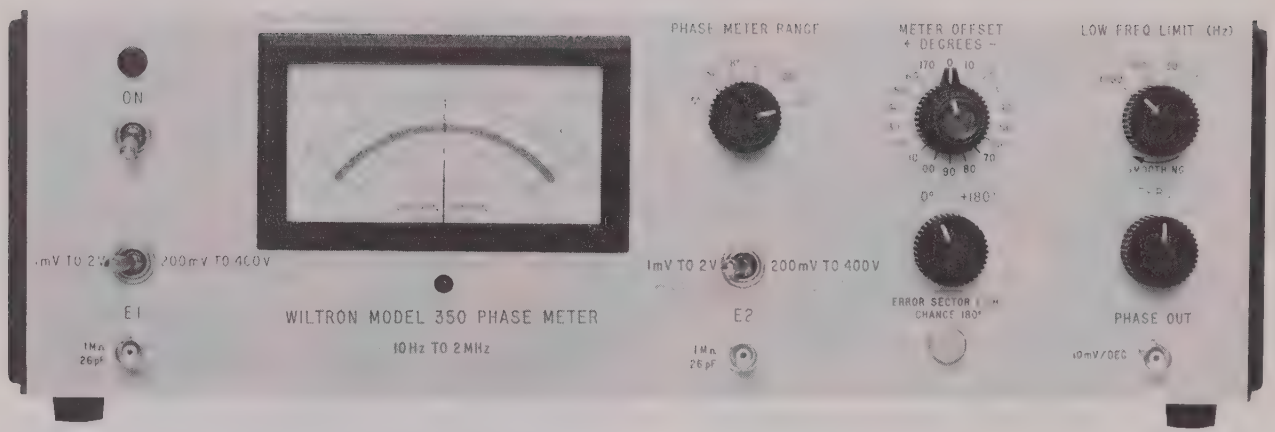


Figure 2-1

Front Panel View

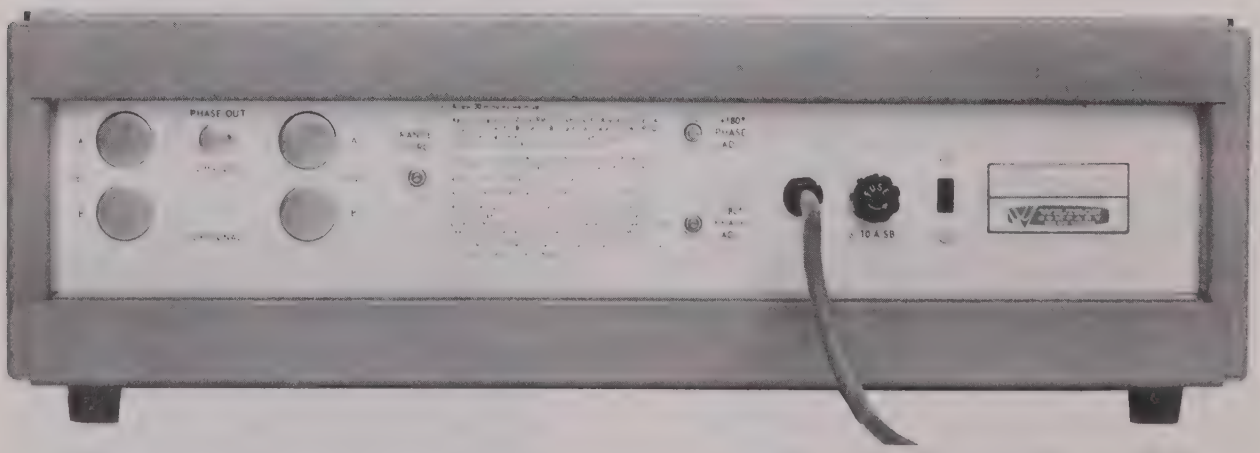


Figure 2-2

Rear Panel View

SECTION III
OPERATION

3-1. FUNCTION OF CONTROLS AND INDICATORS

Table 3-1 lists the functions of the controls and indicators of the Model 350 Phase Meter.

3-2. INPUT AND OUTPUT CONNECTORS

The input and output signal connectors are described in Table 3-1.

Table 3-1. Function of Controls, Indicators, and Connectors

CONTROLS

POWER SWITCH: A two-position toggle switch which turns the phase meter ac power on and off. Power is ON in the up position.

LOW FREQ. LIMIT (Hz): This control has four positions, minimum smoothing being the most counterclockwise. Moved clockwise, the control adds filtering to the output phase measurement signal. It is used to reduce the meter fluctuations which occur at low frequencies or in the presence of a noisy signal, and provides a smooth dc for digital voltmeter use.

0° + 180°: This two-position control switches one of the two input signals from an in-phase (0°) condition to an out-of-phase condition (+180°) with respect to the other. Use of this control makes it convenient to measure phase angles near 180° by moving their meter readings to near the zero part of the scale.

ZERO: This control adjusts the phase reading to an arbitrary zero when any condition exists to cause a slight phase shift reading when the two input signals are known to be exactly in phase. This control can be used to compensate at a single frequency for unequal cable lengths in the E1 and E2 paths.

E1 AND E2 LEVEL SWITCHES: 1mV to 2V/200mV to 400V selector switches: These two-position toggle switches, one above each input connector, selects one of two input ranges depending on the amplitude of input signals applied at E1 and E2 connectors. The ranges labeled are rms values of input voltage.

PHASE METER RANGE: This six-position switch selects meter range. Each position corresponds with a full scale meter range.

METER OFFSET: The outer knob of this dual control offsets the meter phase reading in 10° steps from 0° to 170°. It does this by inserting a dc bias voltage in the meter circuit. Its function is to permit measurement of any phase angle on the most sensitive range of the instrument, that is, within ±5° of the offset value.

The inner knob of this control selects polarity of the offset, positive in left position and negative in right. Polarity of offset is equivalent to polarity of meter reading. For example, if meter reads +90°, offsetting to +90° will bring the meter reading to zero.

Table 3-1 (Cont)

INDICATORS

POWER INDICATOR LAMP: An indicator lamp above the power switch which lights when the phase meter power is on.

ERROR SECTOR LIGHT: The error sector light comes on when the angle being measured is close to 180° and there is an ambiguity between + and - 180°. If the error light comes on when the signals are known to be of sufficient amplitude, throwing the 0° + 180° switch will extinguish the light and move the meter reading into the proper phase range.

CONNECTORS

E1 and E2: Normally, the E1 input connector is used for the reference input and the E2 input connector is used for the test input. If the two interconnections are reversed, the phase reading will merely be of opposite sign.

PHASE OUT: This connector provides a dc output signal proportional to the phase angle at 10 millivolts per degree. This signal is not affected by the position of the METER OFFSET switch.

3-3. PRECAUTIONS TO TAKE FOR STABLE PHASE MEASUREMENTS

The WILTRON Model 350 Phase Meter has an input sensitivity of 1mV on each channel and a bandwidth greater than 5MHz. (The amplifiers have useful gain up to 30MHz). As a result, care must be taken that extraneous signals do not ride in with the desired test signals.

If the phase meter reading fluctuates or the meter occasionally pins itself to full scale, this indicates that spurious signals are reaching the trigger circuits of the phase meter. These may be line transients, spurious noise or RF signal pickup.

There are several ways that unwanted signals can get into the phase meter:

1. Unshielded connection leads.
2. Ground loops.
3. Spurious output signals on the test oscillator or source.
4. Via the ac power line.

These effects can be minimized as follows:

1. Shield the input connections completely. Use low impedance signal lines. Add 0.001μF disc capacitors from the input terminals to ground. If 1mV sensitivity is not required, operate with the attenuator switches in the 200mV position.

2. It is usually best to ground the phase meter and signal sources separately via their power cables, but use a common ac power line. However, some signal sources generate ground currents by their ac line by-pass capacitors. In these cases, an isolation transformer is suggested.

3. Several audio frequency oscillator designs from reputable companies have spurious noise signals and/or waveform kinks which can cause erratic phase meter readings. At WILTRON, Krohn Hite oscillators and Hewlett Packard Models 200 C/D and 651B are used. Other equivalent instruments may be equally suitable.

4. RF by-pass capacitors on the ac line input, and electrostatic shielding in the power transformer make it very unlikely that any form of external line filter will be needed to remove normal levels of ac line interference. In severe cases, the filter may be necessary.

These precautions are not always necessary, depending upon location, etc., but they should be borne in mind in case of difficulty.

NOTE

Optimum performance of the Model 350 is obtained after the internal temperature has stabilized. To avoid warmup time, power to the equipment may be left on for extended periods.

3-4. PHASE MEASUREMENT STEP-BY-STEP PROCEDURE

NOTE

If desired, the accuracy of the instrument can be verified prior to use by performing the procedure given in paragraph 5-5.

1. Select the following front panel control settings:

   PHASE METER RANGE switch to 5°.

   METER OFFSET switch to 0°

   0° + 180° switch to 0°.

   OUTPUT SMOOTHING to the minimum (most counterclockwise)position .

2. Determine the approximate voltage of the signals under test and set the input toggle switches for E1 and E2 to the range in which the test signals are most nearly centered.

3. Set up to divide an input signal into two paths and feed the same in-phase signal into both E1 and E2. A suggested test setup is shown in Figure 3-1. Adjust the ZERO control until the phase meter reads zero.

4. Set the PHASE METER RANGE switch to 180°. Introduce one test signal (reference) into E1 and the other into E2. Read the phase angle on the most convenient range.

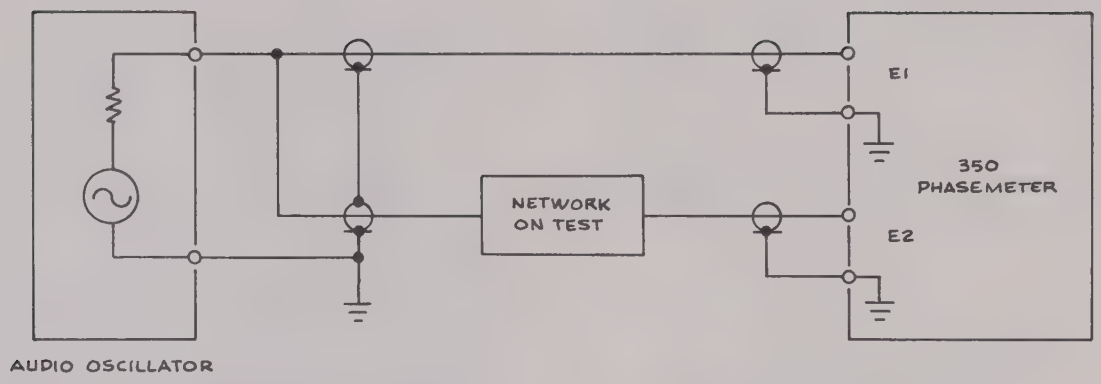
5. For improved resolution in reading a large phase angle, set the PHASE METER RANGE control to ±180°. If it is a positive (+) angle, introduce a positive (+) offset using the METER OFFSET control; if a negative (-) angle, introduce a negative (-) offset. Then turn the PHASE METER RANGE switch to the 10° or 5° range.

6. Make the final phase reading, which is the algebraic sum of the meter and the offset. Note that one reading may be positive and one reading negative, but if they are added taking into account the sign, the resultant will be correct. A positive angle occurs when E2 leads E1. A negative angle occurs when E2 lags E1.

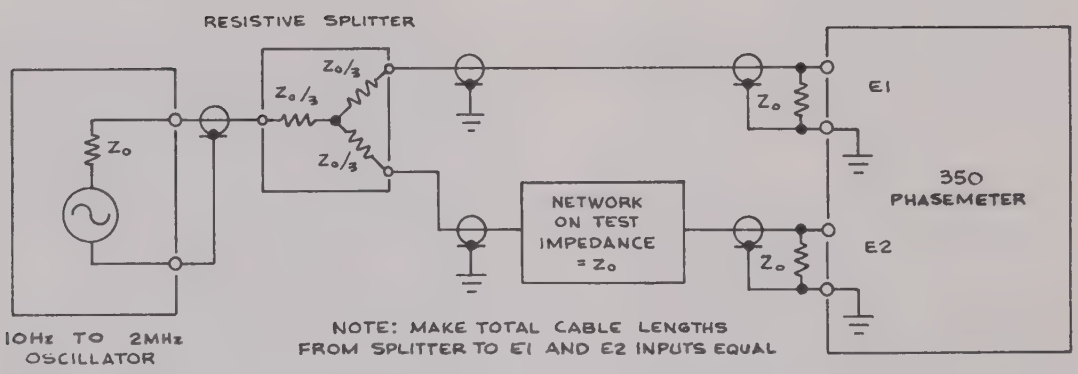
7. Set the LOW FREQ LIMIT control to suit the input frequency. In the 10Hz position, any frequency between 10Hz and 2MHz can be applied. In the 30Hz position, any frequency from 30Hz to 2MHz can be applied and so forth.

8. If the ERROR SECTOR LIGHT is on, do not make the reading, but change the position of the 0° +180° knob to the +180° position and include that angle as a part of the measured result.

9. If the meter reading is erratic, or if it pins to full scale occasionally, refer to paragraph 3-3.



UNBALANCED AUDIO PHASE MEASUREMENTS WITHOUT TERMINATION



AUDIO/VIDEO PHASE MEASUREMENT
IN UNBALANCED CIRCUITS WITH COMPLETE TERMINATION

Figure 3-1. Model 350 Phase Meter, Typical Test Setups

3-5. MINIMIZING ERRORS DUE TO SIGNAL LEVEL OR FREQUENCY VARIATIONS

The most accurate measurements can be made by resetting the ZERO control while applying two in-phase signals at the input levels to be used during the test, as suggested in paragraph 3-4. If this is inconvenient and signal levels or frequencies must be changed during the test, refer to Table 3-2 or Figure 3-4 for typical phase angle measurement errors when the signal levels or frequencies are changed. For very accurate measurements, a table can be made for each individual phase meter, to show its particular zero change due to signal level or frequency variation. This table then can be used to correct the data.

3-6. ACCURACY LIMITATIONS IN MEASURING PHASE ANGLE OF DISTORTED WAVEFORMS

The phase meter makes the phase measurement by detecting the fraction of a cycle between the negative-going zero axis crossing of the reference and the test signal. If the waveform of either signal is distorted so as to change its zero axis crossing (see Figure 3-2), the phase angle reading will be in error. In testing configurations where the signal levels on each channel are similar, this source of error can be removed by making two measurements, as described below.

As shown in Figure 3-1, measure the phase angle of the network under test by connecting the reference input to E1 and the test input to E2. Note the phase angle reading A. Transpose the E1 and E2 inputs. Note the phase angle reading B. The true phase angle T is determined as follows:

$$T = \frac{A + B}{2}$$

Making phase angle measurements in this manner permits accurate measurements with non-sinusoidal test signals. It also cancels errors due to incorrect setting of the ZERO control. More details of the effects of harmonics and spurious noise on the accuracy of the phase angle measurements are described below.

HARMONIC DISTORTION - If there is harmonic distortion of the input signals, the readings can be in error by the following amount:

$$\text{Error in reading} = \frac{D}{100} \times 57°$$

where D = harmonic distortion in percent.

Thus, if 1° accuracy is required, the second harmonic distortion of the input signals must be less than 2%. If both inputs receive signals with harmonics, this is the limit of error in each channel. If the phasing of the harmonics is controlled, the errors may be eliminated by an in-phase relation. For example, a waveform rich in odd harmonics, such as a squarewave, will have no error. Odd order harmonics typically give less distortion because the harmonics tend to maintain a zero phase relationship with the fundamental.

To combat errors due to harmonics, use the the method shown in Figure 3-3 or use filters to eliminate the undesired harmonics. Use the graph, Figure 3-2, to determine the magnitude of error, or to establish the filter reduction factor for a desired accuracy.

NOISE - Errors due to non-coherent signals depend on both the magnitude and the frequency ratio of the non-coherent signal to the signal under test. An undesired signal that is at a fraction of the test frequency gives equal plus and minus errors and thus averages to zero with suitable filtering (smoothing). Error signals greater than 100 f (where f is the fundamental frequency of the test signal) will give an advancement of the zero crossing, resulting in a phase error of magnitude:

$$\phi = \frac{e \times 57^\circ}{a}$$

where e is the magnitude of the error signal and a is the magnitude of the test signal.

For smaller frequency ratios, the average error will be an advancement between zero and $\frac{e \times 57^\circ}{a}$.

These errors are indicated when one test signal input has interfering signals and the other input is pure. If both signals have the same impurity, the errors will tend to cancel except in the coherent case. The same error limits, the same frequency ratio dependence, and the two channel cancellation effects occur with random noise error signals as with harmonic distortion. The rms value can be used to calculate the limits.

Note that the use of a pair of identical low pass filters added at the inputs will remove the high frequency components, which are the principal error producers.

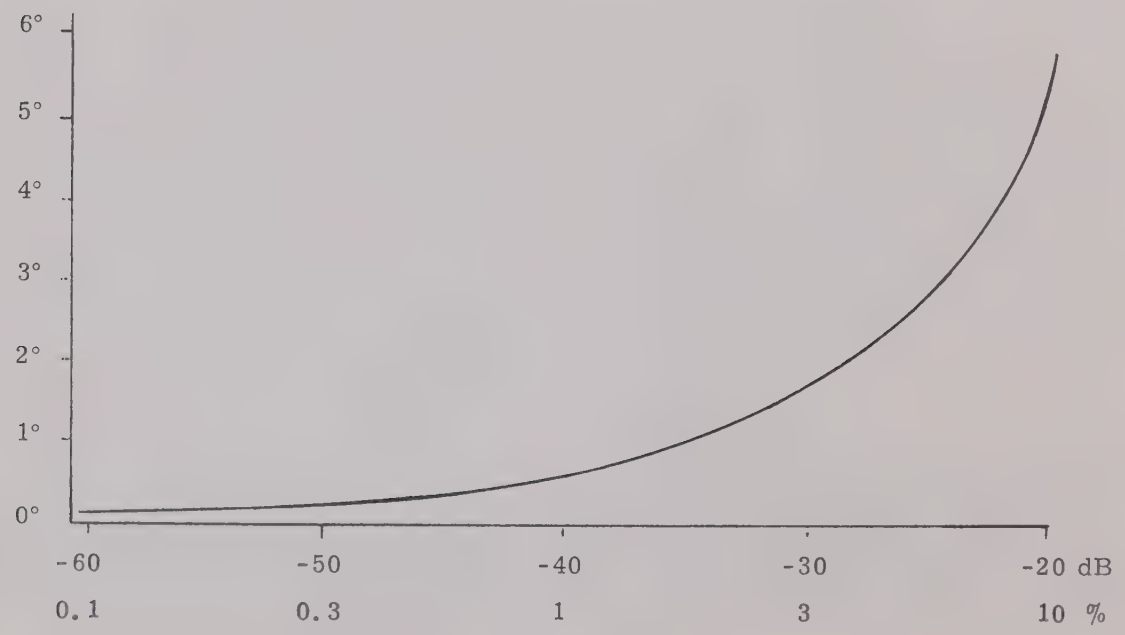


Figure 3-2. Phase Angle Error as Function of Harmonic Distortion

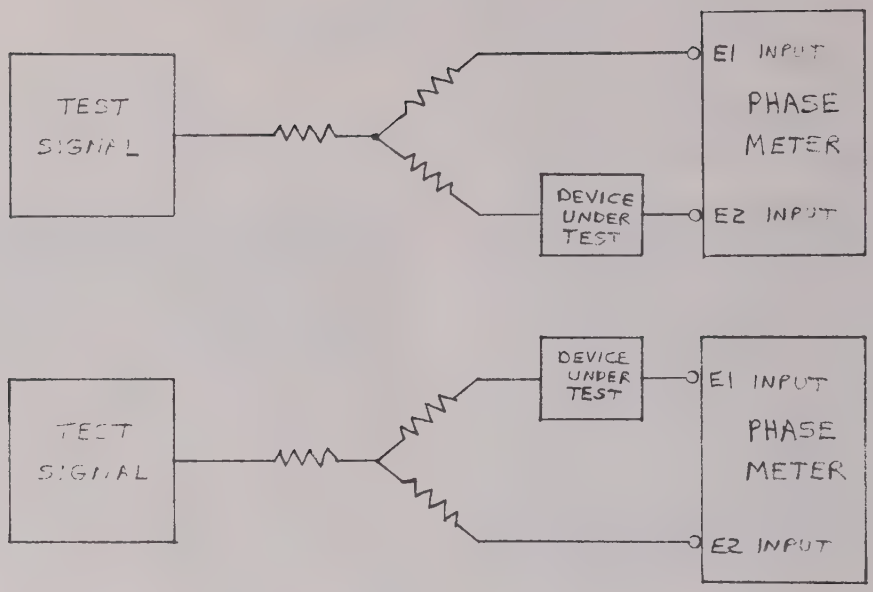


Figure 3-3. Cancelling Effect of Distorted Signals

Table 3-2. Display Readout Zero Change Due to Signal Level Variations

E1 Input	Degrees						
1 V (200 V)	1.5	1.0	0.7	0.3	0.3	0.3	0.3
300 mV (60 V)	1.3	0.7	0.5	0.2	0.2	0.2	0.3
100 mV (20 V)	1.0	0.7	0.4	0.2	0.2	0.2	0.3
30 mV (6 V)	1.0	0.4	0.2	0	0.2	0.2	0.2
10 mV (2 V)	0.8	0.4	0.2	0.2	0.4	0.5	0.7
3 mV (600mV)	0.5	0.2	0.2	0.2	0.4	0.7	1.0
1 mV (200mV)	0.5	0.4	0.4	0.4	0.7	1.0	1.5
E2 Input	1 mV (200mV)	3 mV (600mV)	10 mV (2V)	30 mV (6 V)	100 mV (20 V)	300 mV (60 V)	1V (200 V)

NOTE

The E1 and E2 inputs are shown for both positions of the input attenuator switches. Input values in parentheses correspond to the low range 1 mV to 2V position of the switches.

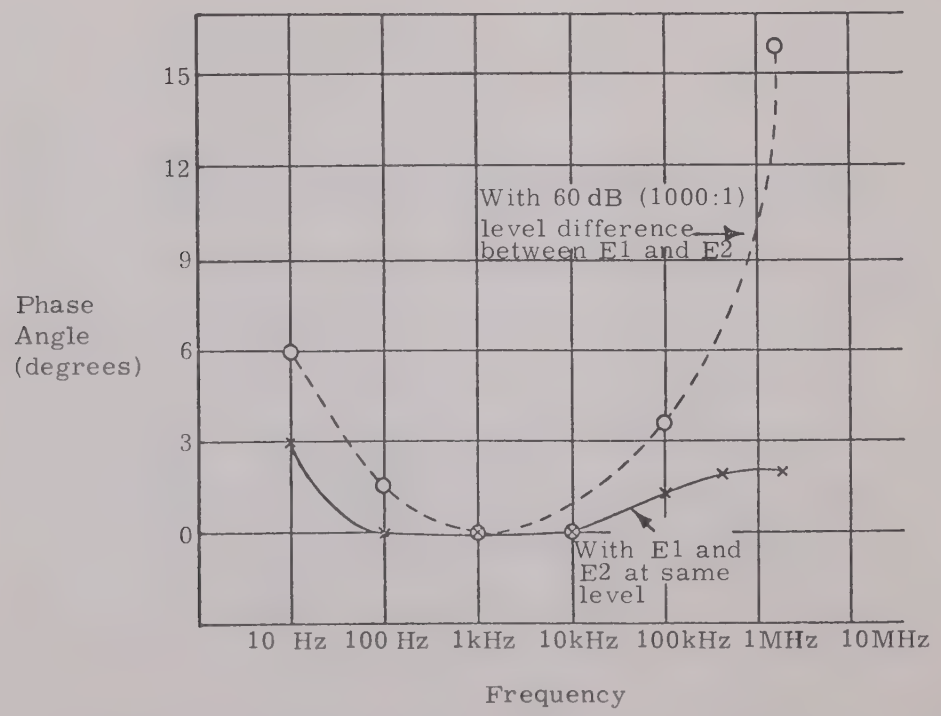


Figure 3-4. Display Readout Zero Change Due to Input Frequency Variations

SECTION IV

THEORY OF OPERATION

4-1. OVERALL FUNCTIONAL DESCRIPTION

Refer to the functional block diagram, Figure 4-2. Each input signal is processed through a source follower and amplifier having three limiting stages and one non-limiting output stage. A Schmitt trigger circuit produces a negative output pulse coincident with the negative going crossing of the average value of the amplified signal. These pulses cause the phase detector multivibrator to change back and forth between its two bistable states. The average dc component of the resultant output wave from one side of the multivibrator is a measure of the time difference between the two negative-going zero crossings.

This waveform is filtered by the active smoothing filter circuit to a dc voltage, which is directly proportional to the measured phase angle. This voltage varies 10mV per degree of measured phase angle difference and has maximum usable excursions of +1.80V to -1.80V. This dc voltage is available at the PHASE OUT connector and is also applied to the meter amplifier where it is appropriately scaled and offset for the panel meter display. See Figure 4-1.

Typical waveforms from input terminals through the instrument to meter readings are shown in Figure 4-3 for phase angles of 0°, ±90°, and ±180°. The waveforms labeled TP9 and TP10 represent the inputs to the Schmitt triggers, and TP11 and TP12 the output pulses from the Schmitt triggers. The waveform at TP13 is the output square wave of the phase detector multivibrator, as Q302 switches between off and on states as shown by the MVBR INPUT waveform. The average dc component which causes the meter reading is shown by dash lines on the TP13 waveform.

Condition (d) Figure 4-3 results in an ambiguity for a phase angle at or near 180° because of the discontinuity in the output dc voltage inherent in any linear phase detector covering a full 360° range. When the phase angle being measured is within a few degrees of 180°, the error detector circuit senses this nearness and lights the ERROR SECTOR LIGHT on the front panel. Changing the 0° +180° switch to the +180° position inverts the E2 signal and shifts the zero crossing back into the working range of the phase measuring circuits.

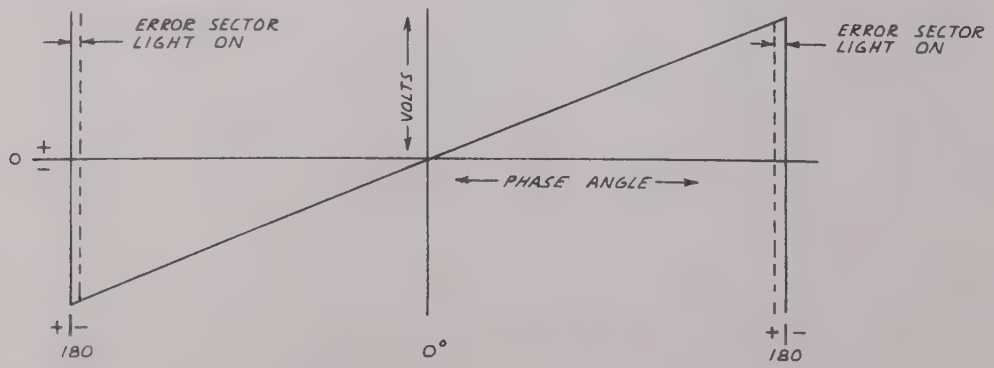
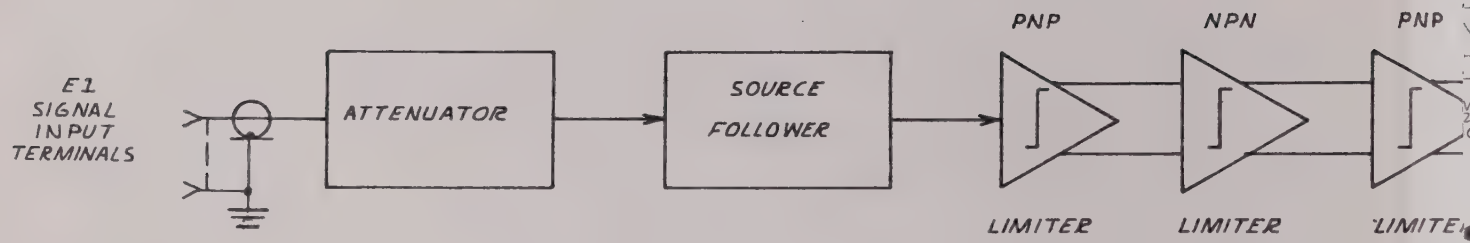
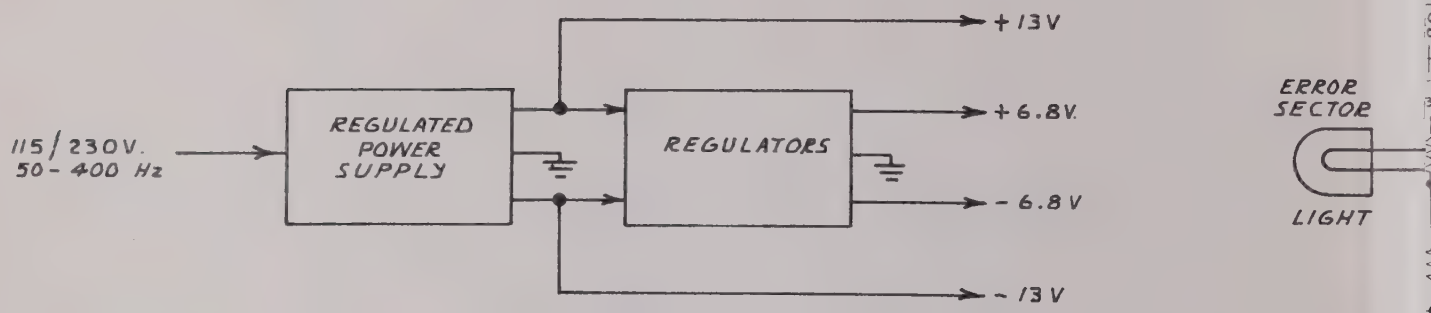
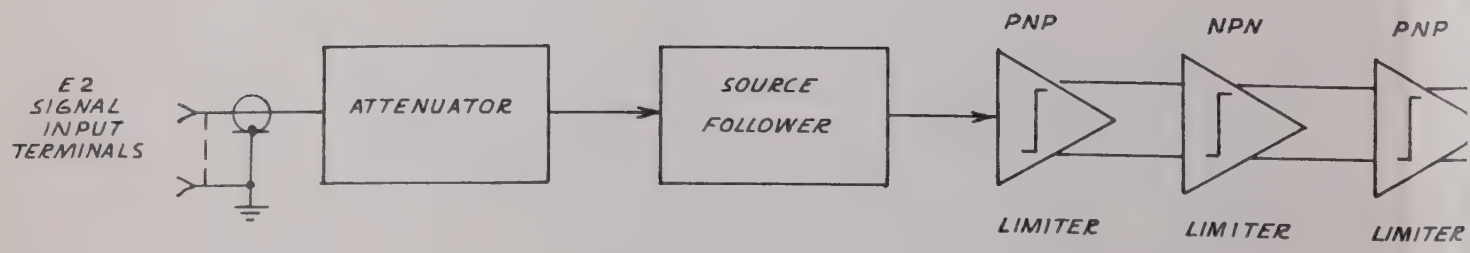


Figure 4-1. Phase Detector Characteristics


E1
SIGNAL
INPUT
TERMINALS
ATTENUATOR
SOURCE
FOLLOWER
PNP
NPN
PNP
LIMITER
LIMITER
LIMITE


115/230V.
50-400 Hz
REGULATED
POWER
SUPPLY
REGULATORS
+13V
+6.8V
-6.8V
-13V
ERROR
SECTOR
LIGHT


E2
SIGNAL
INPUT
TERMINALS
ATTENUATOR
SOURCE
FOLLOWER
PNP
NPN
PNP
LIMITER
LIMITER
LIMITER

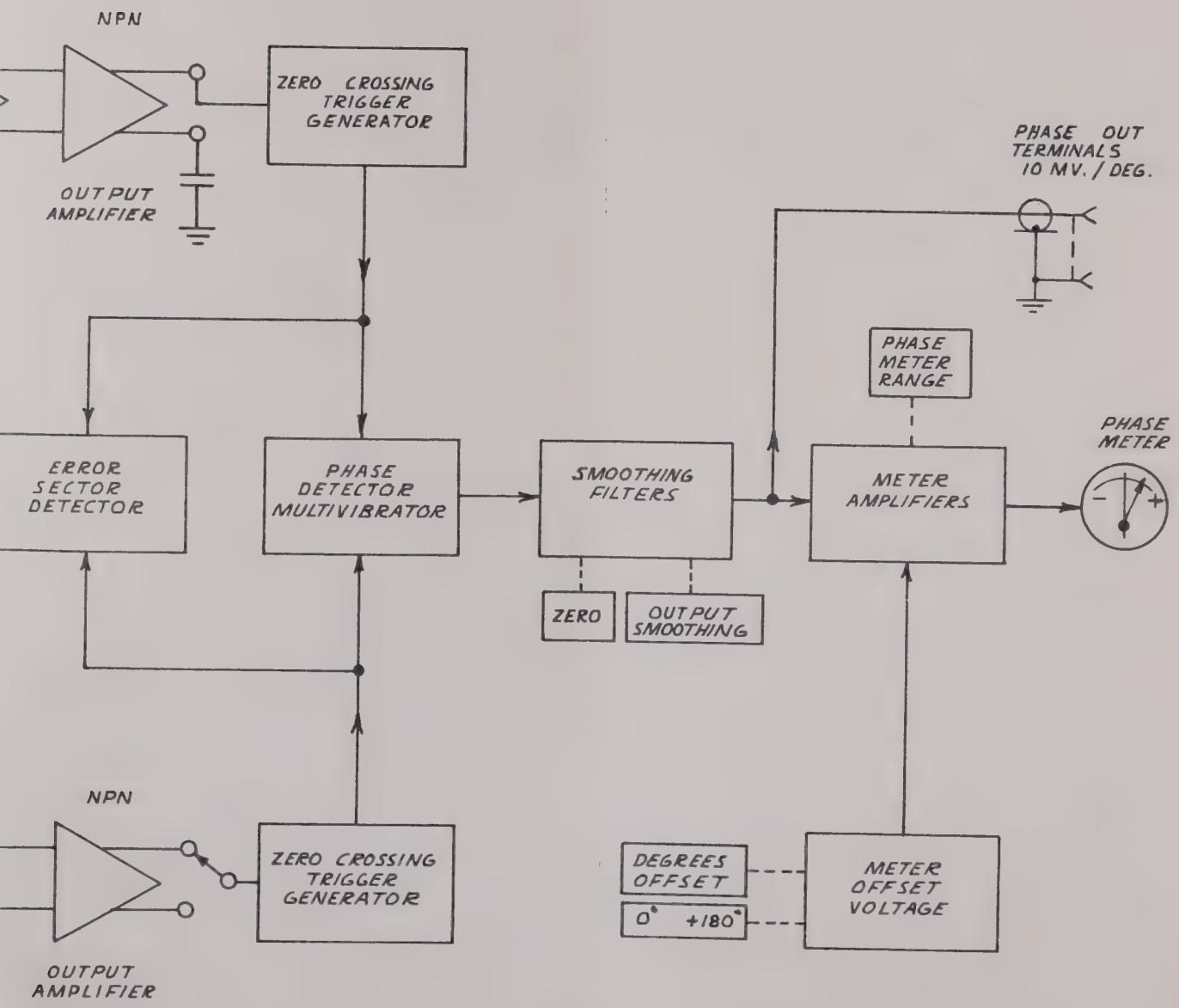
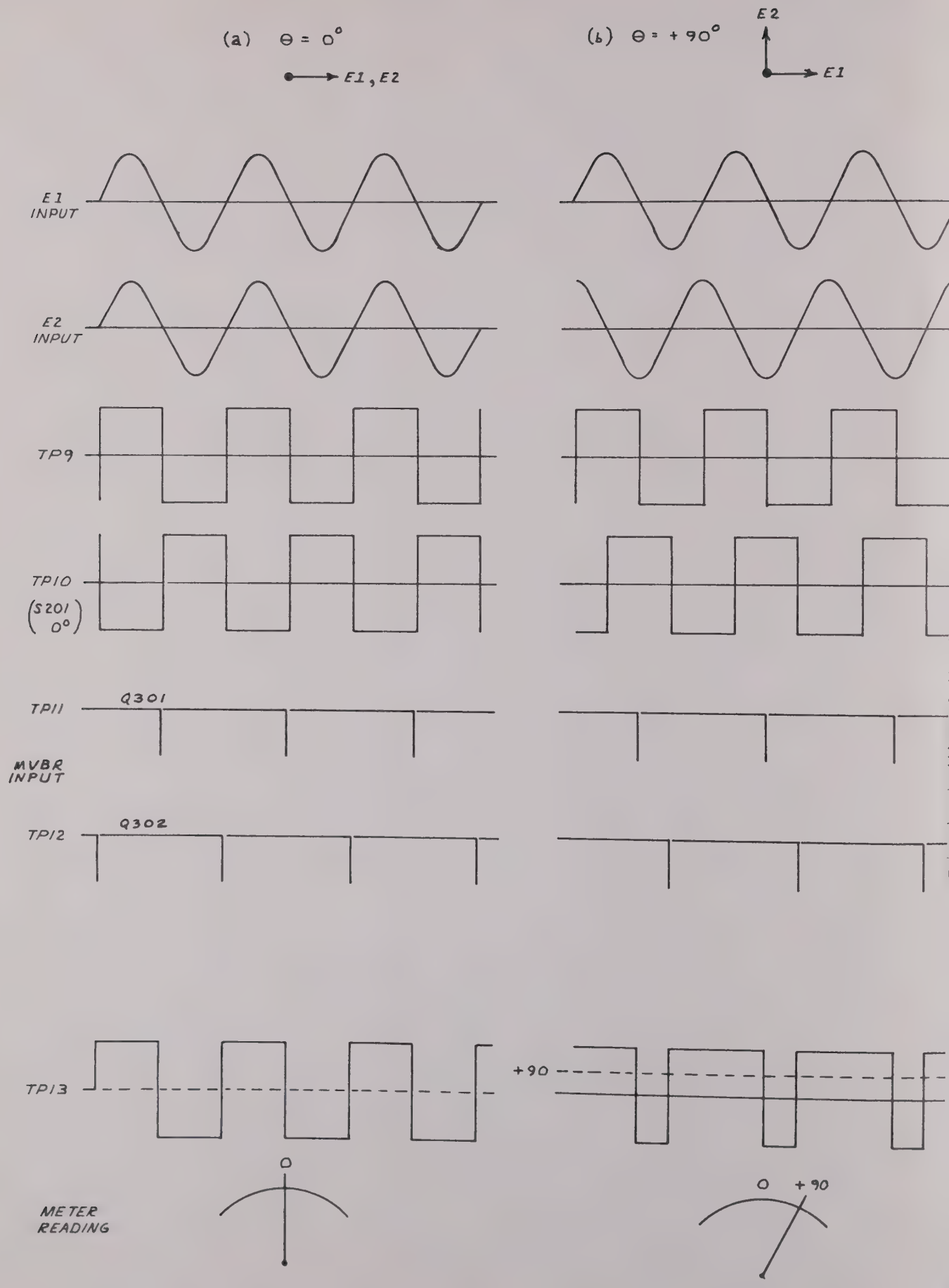


Figure 4-2. Functional Block Diagram


(a) Θ = 0°
E1, E2
(b) Θ = +90°
E2
E1
E1 INPUT
E2 INPUT
TP9
TP10
(S201 0°)
TP11
Q301
MVBR INPUT
TP12
Q302
TP13
+90
METER READING
0
0
+90

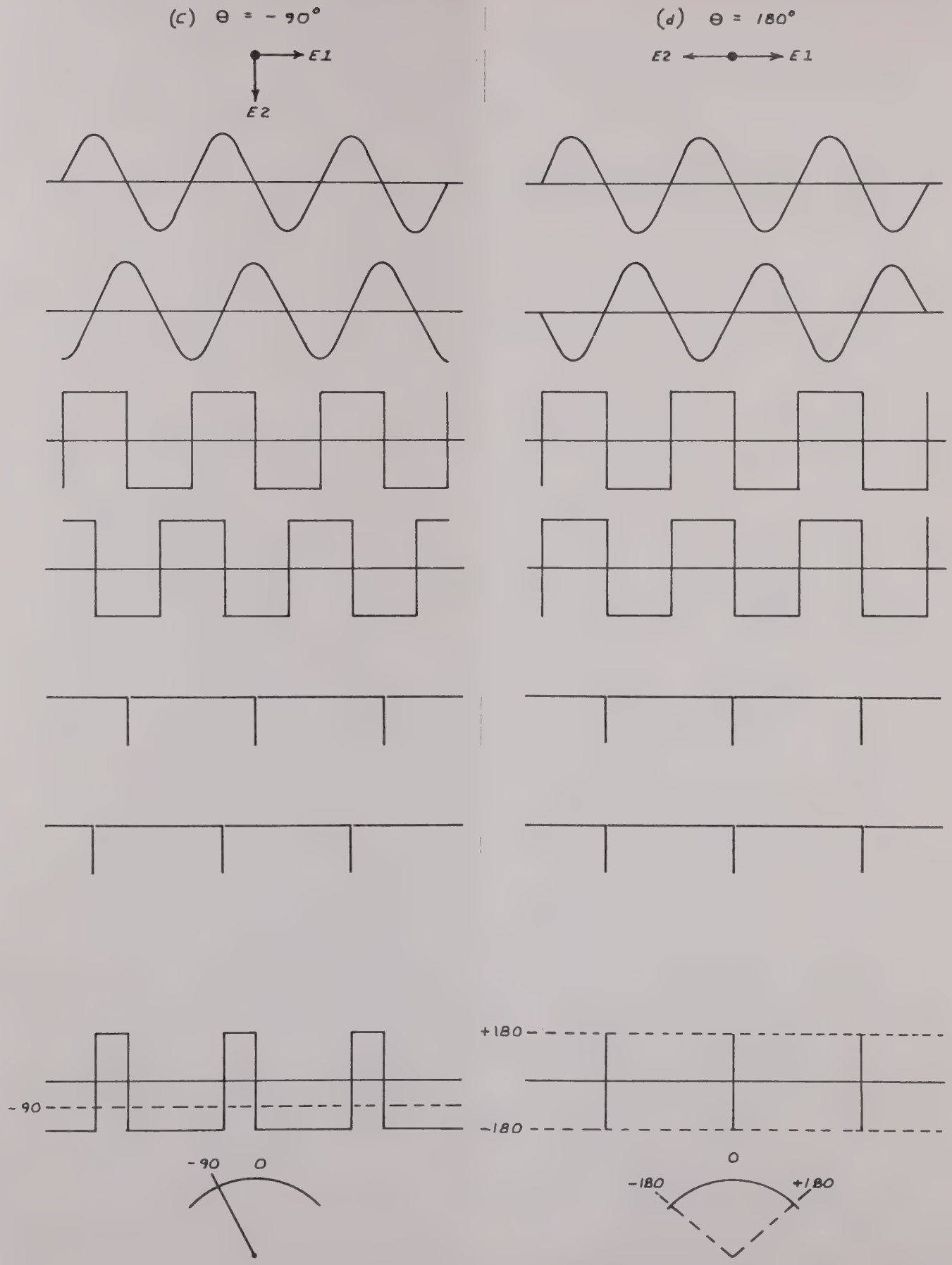


Figure 4-3. Waveforms at Four Angles

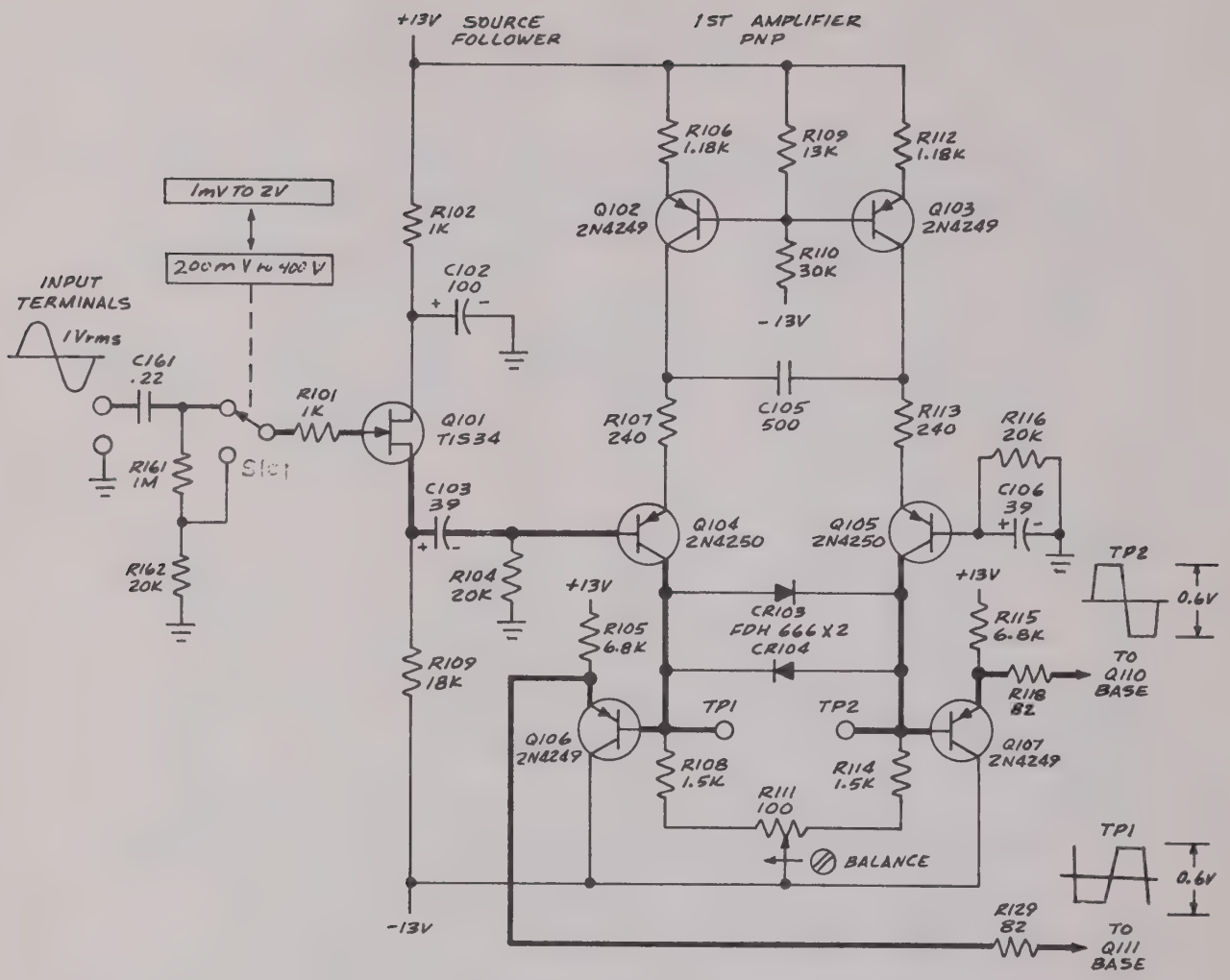


Figure 4-4. Source Follower and First Amplifier, Simplified Schematic Diagram

4-2. OPERATIONAL SCHEMATIC DIAGRAMS

Simplified schematic diagrams of each main section of the instrument, which illustrate the signal processing in greater detail, are included in Figures 4-4 through 4-8. Signal paths are shown by heavy lines and waveform shapes at the input and output of each stage.

Reference may also be made to the detailed schematic diagrams provided in Section VII of the manual.

4-3. SOURCE FOLLOWER AND FIRST AMPLIFIER (Figure 4-4)

The source follower and amplifier circuits are shown for only one signal amplifier board, the other being identical. S101 selects the amplitude of input signal to be applied to the gate of source follower FET Q101. The follower output is applied to the first balanced amplifier Q104 and Q105, a PNP stage. Q102 and Q103 are current regulators, Q106 and Q107 emitter followers feed the output signal to the next stage. Test Points TP1 and TP2 allow oscilloscope checks of output signals applied to Q111 and Q110, respectively.

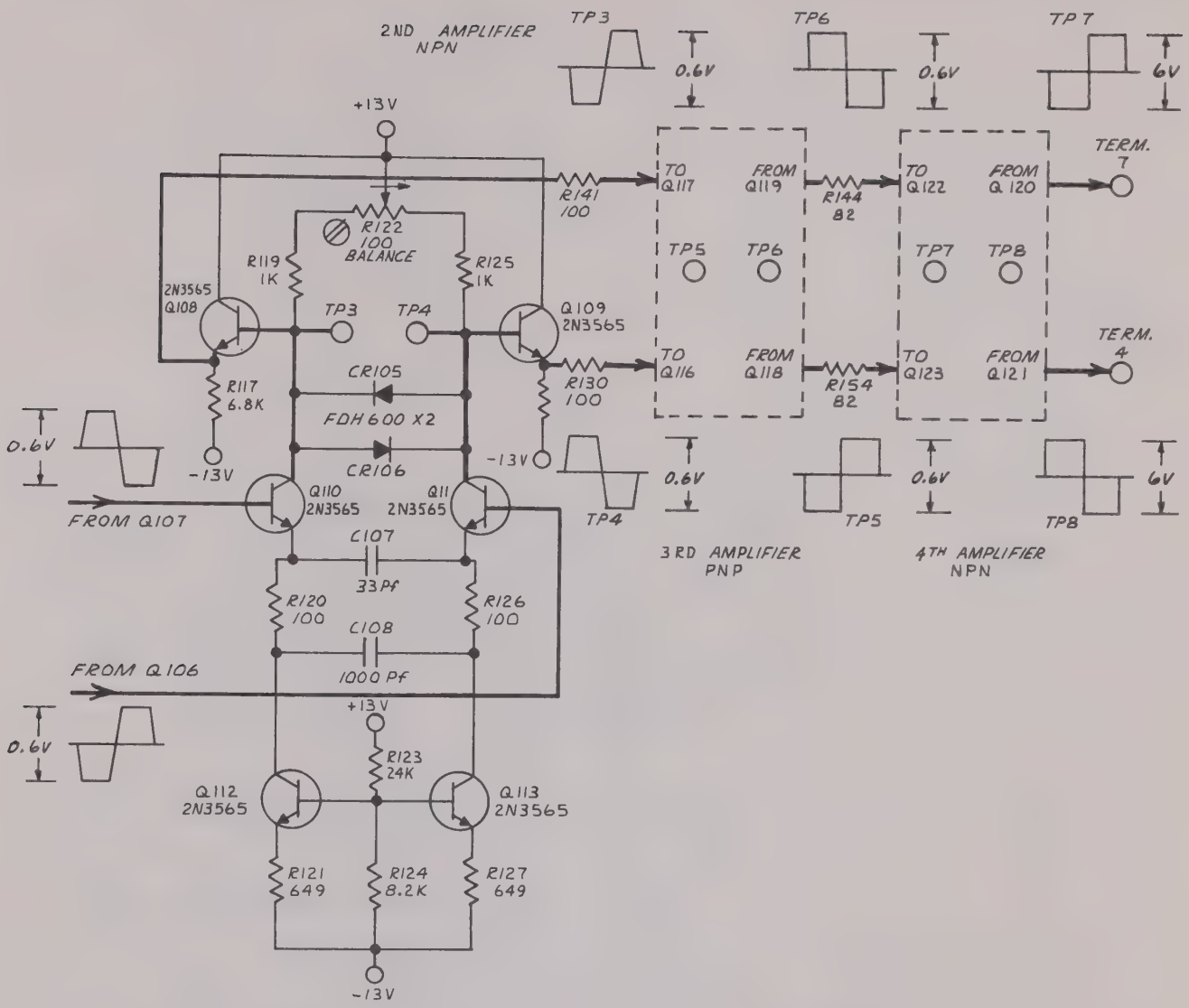


Figure 4-5. Second, Third, and Fourth Amplifiers, Simplified Schematic Diagram

4-4. SECOND, THIRD AND FOURTH SIGNAL AMPLIFIERS (Figure 4-5)

Q110 and Q111 comprise the second balanced amplifier, an NPN stage. Alternate PNP and NPN stages are used in the amplifier to permit direct coupling. Q112 and Q113 are current regulators, and Q108 and Q109 are output emitter followers. TP3 and TP4 are used to monitor the output waveforms of this stage.

The third amplifier, Q116 and Q117 is the same as the first amplifier, and the fourth, Q122 and Q123, the same as the second, except that the fourth has no limiter diodes in the collector circuit. TP7 and TP8 are used to check the output waveforms of the fourth stage, which should be steep-slope square waves for any amplitude of input signal within the rated input range. The output square wave in phase with the A input is brought to numbered terminal 4 on the amplifier board; the one in phase with the B input goes to numbered terminal 7.

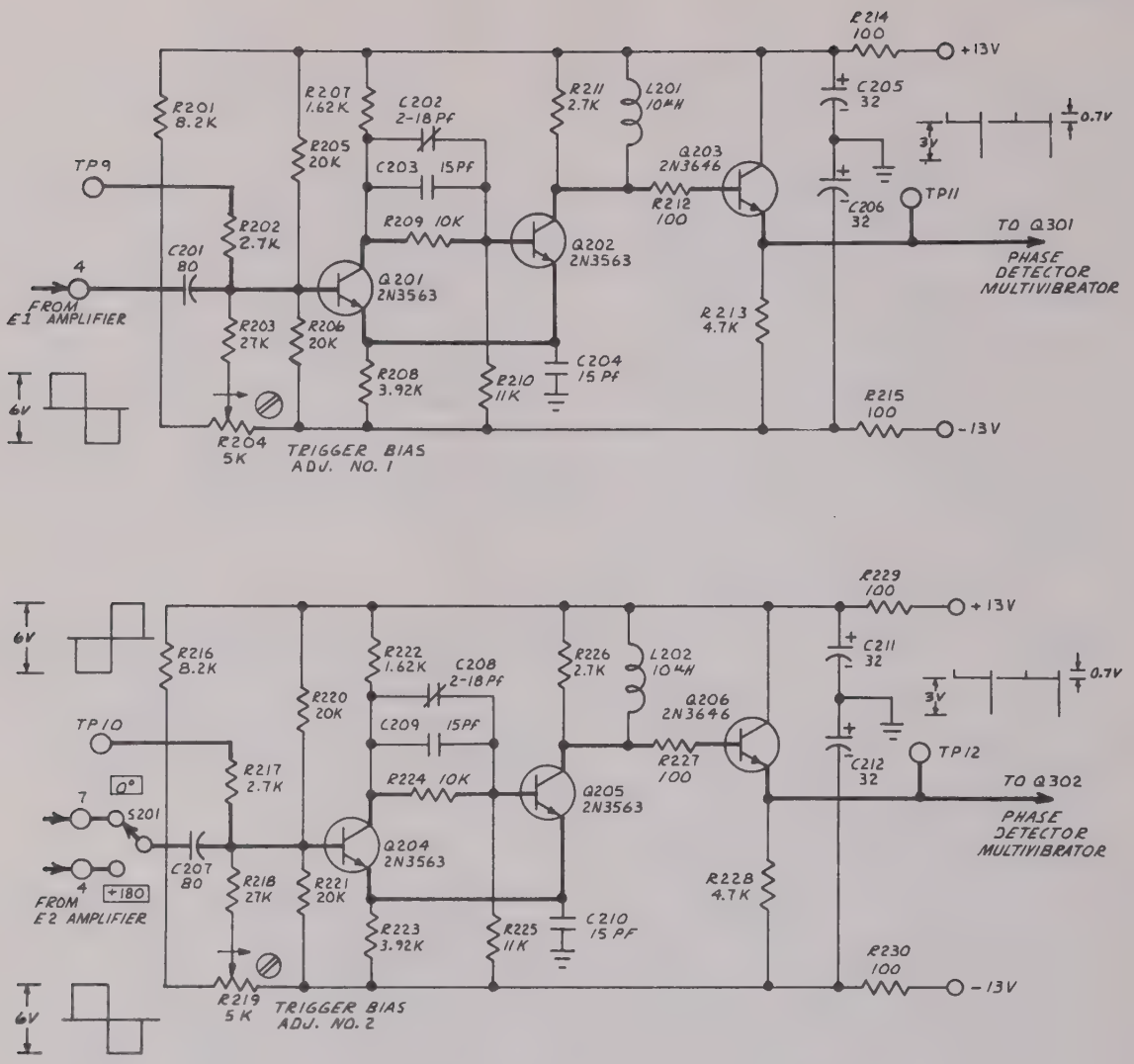


Figure 4-6. Trigger Circuit, Simplified Schematic Diagram

4-5. TRIGGER CIRCUITS (Figure 4-6)

Note that the E1 trigger circuit uses input from the E1 amplifier board terminal 4 only, the non-inverting phase same as A. The E2 trigger circuit input is from the E2 amplifier board terminal 7, the inverting phase same as B, with S201 in the 0° position. With the switch in the +180° position, the non-inverting phase A from terminal 4 on the E2 amplifier board is used. The effect of using the 0° + 180° switch is thus to shift the phase of the E2 trigger input by 180°.

Q201 - Q202 (E1 channel) and Q204 - Q205 (E2 channel) are Schmitt trigger circuits which switch between two bistable states with very fast switching times when their input voltage varies only slightly (about half a volt) above and below a preset level. Trigger bias adjustments R204 and R219 set the dc bias of the input circuits to equal the lower trigger level of the Schmitt circuits. Thus, the ac coupled signals from the E1 and E2 amplifiers swing the trigger circuit inputs equally above and below this level.

Refer to the E1 trigger circuit)the E2 circuit description being the same). As the signal crosses the lower trigger level in the negative-going direction, Q201 is turned off and Q202 is turned on. The negative step developed across R211 is differentiated into a narrow pulse by L201 and delivered by the emitter follower Q203 to the phase detector multivibrator. The Schmitt trigger is reset when the signal crosses the upper trigger level. Q201 is turned on and Q202 turned off. The base collector junction of Q203 acts as a clamp to prevent the formation of a positive tail on the output pulses. Input signals to the Schmitt triggers can be observed at TP9 and TP10; output pulses at TP11 and TP12.

4-6. PHASE DETECTOR MULTIVIBRATOR (Figure 4-7)

Negative input pulses from the E1 and E2 trigger circuits are coupled to Q301 and Q302, respectively. The output of the symmetrical triggered multivibrator Q301 - Q302 is taken from the collector of Q302 and can be measured at TP13. E1 trigger pulses turn on Q302 and cause a negative output step. E2 trigger pulses turn off Q302 and cause a positive output step. The relative phase difference between the E1 and E2 pulses determines the duration of the positive and negative steps and the resultant amplitude and direction of the dc component in the output. When the E1 and E2 pulses are displaced by 180°, the output wave becomes a square wave with a zero dc component. When the input pulses are in phase, the multivibrator is unstable, the error sector light comes on, and the 0° +180° switch is used to displace the input pulses by 180°.

Output smoothing of the dc component in the output of Q302 is accomplished by switching in three successively greater values of capacitance as low-pass filters. C314 and C317 form the first step, C313 and C316 the second step, and C315 alone the third.

4-7. METER AMPLIFIERS AND OFFSET CIRCUIT (Figure 4-8)

The dc component of the phase multivibrator output is applied to one input of a balanced dc differential amplifier consisting of two Darlington pairs Q303 - Q304 and Q305 - Q306. Output voltage from a voltage divider across the 6.8 volt regulated dc supply is applied to the other amplifier input. Polarity of the offset voltage is selected by S304 which determines the polarity across the voltage divider. Amount of offset is selected by an 18-point switch S303 connecting to equal resistance taps on the voltage divider.

Phase meter range is selected by a 6-position switch, S302 which changes the sensitivity of the meter amplifier by inserting different values of precision resistance between the emitters of Q304 and Q305.

The meter amplifiers form a dc bridge which is balanced and yields a zero meter reading when there is no dc input component applied to Q303, and S303 is set at the zero degrees offset position. A positive dc voltage at Q303 increases current in Q304, decreases current in Q305, increases voltage at the + terminal of the meter and causes the meter to read positive due to current flow from right to left. Advancing the offset switch S303 will then increase the positive voltage to Q306 and tend to return the meter reading to zero. By offsetting as close as possible to zero and then switching to the most sensitive meter range, a phase reading can be obtained with high accuracy as the algebraic sum of the offset and the meter reading. For a negative input to Q303, S304 would first be switched to the - position, then the same offset procedure as described above would apply.

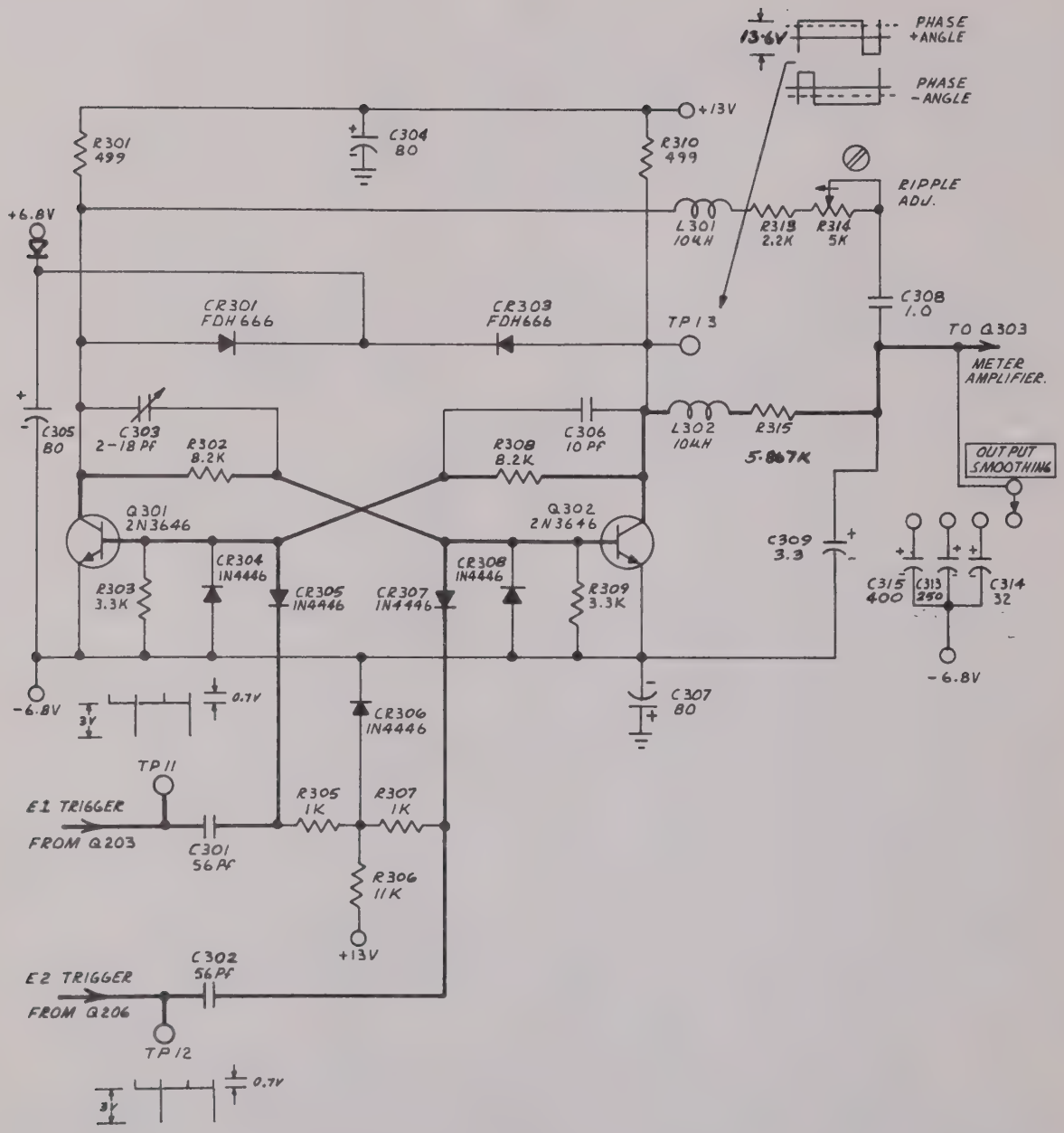


Figure 4-7. Phase Detector Multivibrator, Simplified Schematic Diagram

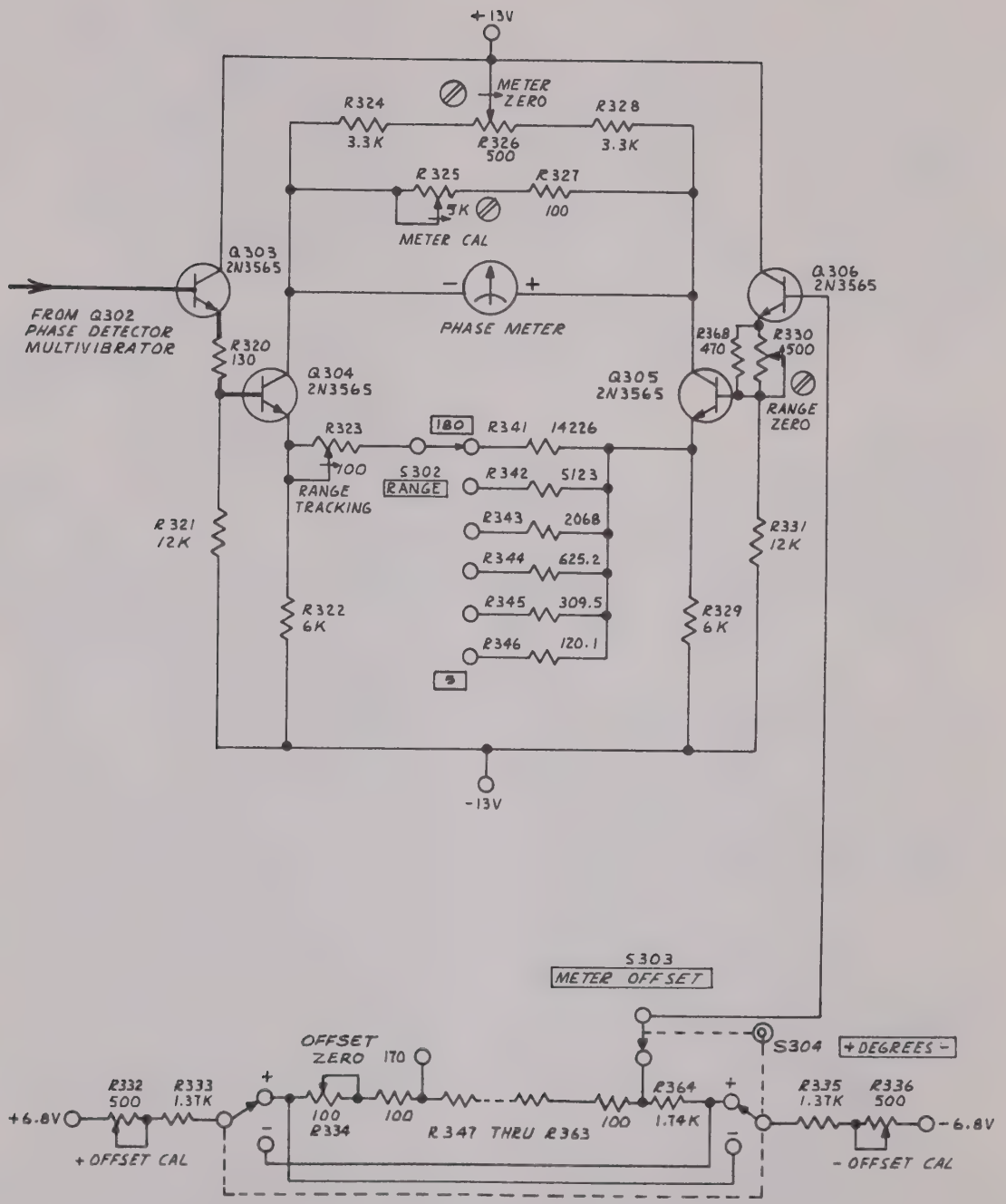


Figure 4-8. Meter Amplifiers and Offset Circuit, Simplified Schematic Diagram

4-8. ERROR SECTOR LIGHT (Figure 7-2)

The function of this circuit is to energize lamp DS201 whenever the output pulses from the E1 and E2 Schmitt trigger circuits become nearly coincident, the condition for phase angles approaching 180°. E1 pulses from Q203 and E2 pulses from Q206 are applied to an "AND" circuit consisting of the diode network and circuit of CR201-4. Providing that none of the area of an E2 pulse coincides with an E1 pulse, the output pulses at the emitter of Q207 are too small in amplitude to trigger the one-shot multivibrator Q208-Q209. Under these conditions Q209 is on, Q208 is off, and Q210 is off, thus keeping the light out.

At some phase angle near 180°, a portion of the E2 pulse will coincide with the E1 pulse. Regardless of the width of the portion coinciding, a pulse will result at the emitter of Q207 that is capacitively coupled through diode CR208 to Q209, cutting off Q209 and turning on Q208. The time constant of C218 and R241 will maintain this condition for 25 milliseconds, during which time Q210 is on and the lamp is lit. For input frequencies above about 40Hz, the lamp will be lit continuously, and at lower frequencies, it stays lit continuously down to about 24Hz where flicker will start to become noticeable. When the lamp is lit, it signals the need of shifting the E2 signal 180° by changing the position of the 0° + 180° switch. This action moves the E2 pulses to 180° out of phase with the E1 pulses, extinguishing the lamp and transferring the meter reading to zero.

If the 0° + 180° switch is operated when the meter reading is near zero, the error sector light may or may not come on. As discussed, this circuit senses when phase angles near to 180° are present, the waveforms must be within 0.2μsec of each other for the circuit to operate. The front panel zero control does not affect whether the light is on or not because it is not a phase shifting control.

4-9. POWER SUPPLY AND REGULATORS (Figure 7-4)

The power supply can be considered in two parts. The first part is a 26 volt regulated supply and the second part is an electronic voltage splitter that divides the 26 volts evenly into plus and minus 13 volts, referenced to ground.

The unique part of the 26 volts regulated supply is that the 5.9 volt reference is used to control a current source Q405. The constant current through R413 creates a constant voltage that is referenced to the plus 13 volt buss. It is used as a reference voltage for one transistor of differential amplifier Q403 and Q404.

The voltage splitter compares the voltage from voltage divider R415 and R416 to ground in a differential amplifier. The output from the differential amplifier is amplified in Q408. Q409 and Q410 cannot both be on at the same time because the base emitter junction of one is reversed biased while the junction in the other is forward biased. Q409 shunts current to ground from the +13 volt buss and Q410 shunts current from the -13 volt buss. Therefore, current can be shunted from one side of the power supply or the other side to make loading equal for both sides and the output from the 26 volt regulated supply is split in two parts to become the +13V and -13V supplies.

The 5.9 volt reference voltage is obtained from a voltage divider across Zener diode CR411. The upper portion of the voltage divider consists of R424 and R425. Either one, both or neither may be shorted at terminals 35, 36 and 37 as a means of obtaining an accurate 5.9 volt supply.

Note: This Unit Must Warm Up For 30 min Before Calib.

SECTION V
MAINTENANCE

5-1. INTRODUCTION

This section contains information required to maintain optimum performance of the phase meter and to locate and repair malfunctions.

5-2. TEST EQUIPMENT REQUIRED

Table 5-1 lists the test equipment required to perform the procedures in this section. Equipment with equivalent characteristics may be used if the specified items are not available. Common hand tools are not listed.

Table 5-1. Test Equipment Required

OSCILLOSCOPE (with 10 to 1 Probe): Tektronix Model 543 with Type 'L' Plug-In.

DIGITAL OR DIFFERENTIAL VOLTMETER: Greater than 10 Megohm Input Impedance, Fluke Model 871.

AUDIO OSCILLATOR: 10Hz to 2MHz, Hewlett-Packard 651B.

ATTENUATORS (2): 10dB calibrated steps, Hewlett-Packard 355D.

RESISTIVE SPLITTER: 50 ohm, two way, WILTRON 3211.

50 OHM THROUGH TERMINATIONS (2): Tektronix 011-0049-00.

BNC TYPE SHORTING CONNECTOR

100K OHM RESISTORS (2): 1/4W, 1%.

1.0ρF CAPACITOR

3.3ρF CAPACITOR

5-3. PREVENTIVE MAINTENANCE

The phase meter normally requires no servicing during operation. If, however, it is operated in an extreme environment, dust, for example, periodic cleaning should be performed according to standard laboratory practices.

WARNING:

HAZARDOUS VOLTAGES ARE PRESENT WITH THE COVERS REMOVED. ALWAYS DISCONNECT AC POWER AT THE SOURCE BEFORE CLEANING.

5-4. PERFORMANCE VERIFICATION

The following procedure may be used to check that the Phase Meter is operating within specifications. This check may be performed prior to each use, daily, or periodically as desired, to ensure accurate measurements. The remaining procedures are used when a complete lab-type performance verification is desired.

5-5. INITIAL PERFORMANCE VERIFICATION

1. Check that power to instrument is turned off. Note meter reading using the ±5° scale. If reading exceeds 0.05° from zero, readjust the mechanical zero of the meter through the panel access hole using a small screwdriver.

2. Turn instrument power on. Allow at least 30 minutes warmup. Set the front panel controls to the standard control settings (see Table 5-2).

3. Connect test equipment as shown in Test Setup A of Figure 5-1. Adjust ZERO control to read exactly zero with PHASE METER RANGE switch at ±5°. Rotate PHASE METER RANGE switch through all positions and note change in meter indication. Pointer should move less than 0.1° as read on ±5° scale.

4. Connect a DVM to PHASE OUT connector. Adjust ZERO control for 0±1mV DVM reading. Set PHASE METER RANGE switch to ±5°. Phase meter should indicate 0°±0.2°.

5. Set test oscillator frequency to 10Hz and note extent of meter pointer flutter. Rotate LOW FREQ LIMIT control clockwise to each position and note progressive reduction of pointer flutter.

NOTE

This check should reveal any faulty contact or smoothing capacitor. Return LOW FREQ LIMIT control to 1000Hz and set test oscillator to 1kHz. Note that meter time constant is shorter as switch is rotated from 10Hz to 1000Hz.

6. Set PHASE METER RANGE switch to ±10°. Adjust ZERO control for zero phase meter reading. Set METER OFFSET control to +10°. Meter should read -10°±2% of full scale. Set METER OFFSET control to -10°. Meter should read +10°±2% of full scale. Using appropriate control settings, check each range of PHASE METER RANGE switch.

7. Check the ±5° range by setting METER OFFSET control to 0° and adjusting ZERO control for a 5.0° reading. Set PHASE METER RANGE switch to ±10°. Meter should read 5°±0.2°.

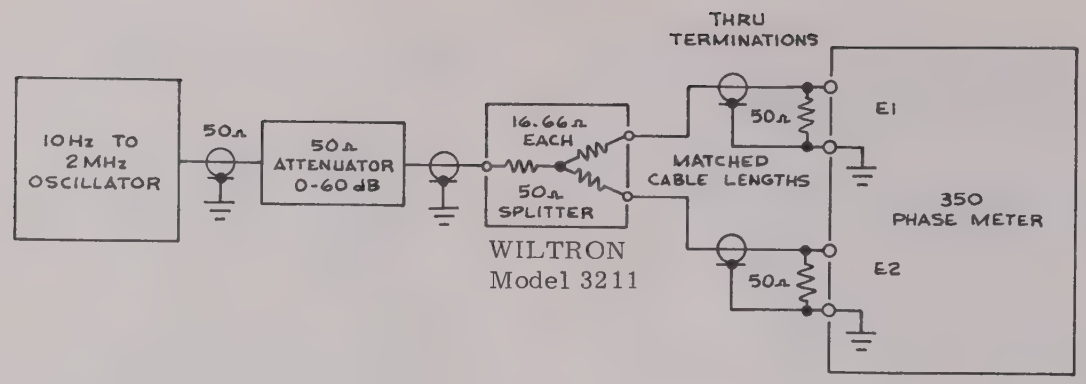
8. Set controls to standard settings (see Table 5-2). Adjust ZERO control to obtain a 0.000 reading on DVM. Remove signal input to E2 and replace with a short. Use either a BNC type shorting connector or a very short length of bus wire to prevent the possibility of a long lead acting as a loop antenna. The DVM should indicate -1.800 volts ±4.0mV ± the DVM accuracy.

   If occasional jumps in the reading are noted, see precautions relating to shielding input leads and eliminating ground loops as described in paragraph 3-3. In extremely noisy environments, calibration confirmation can still be accomplished by connecting a 0.001μF or 0.0001μF disc ceramic (high frequency) capacitor across the input terminals.

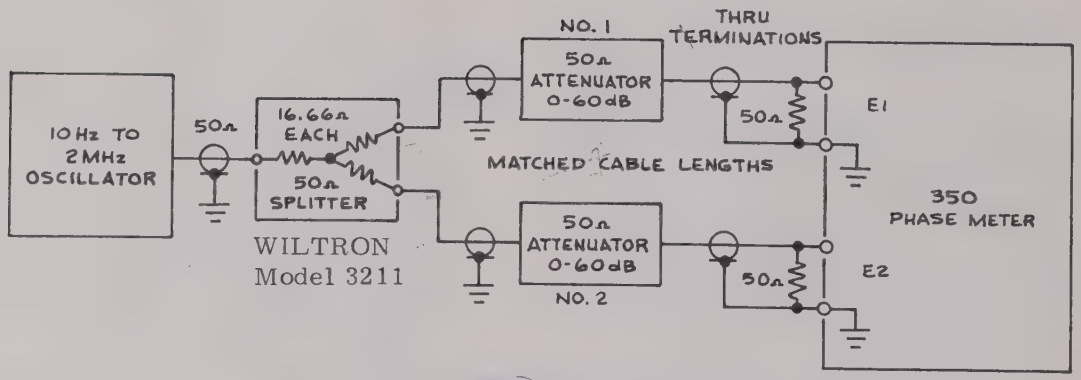
9. Replace the signal to E2 and similarly apply the short to E1. The DVM should should indicate +1.800 volts ±4.0mV ± the DVM accuracy.

NOTE

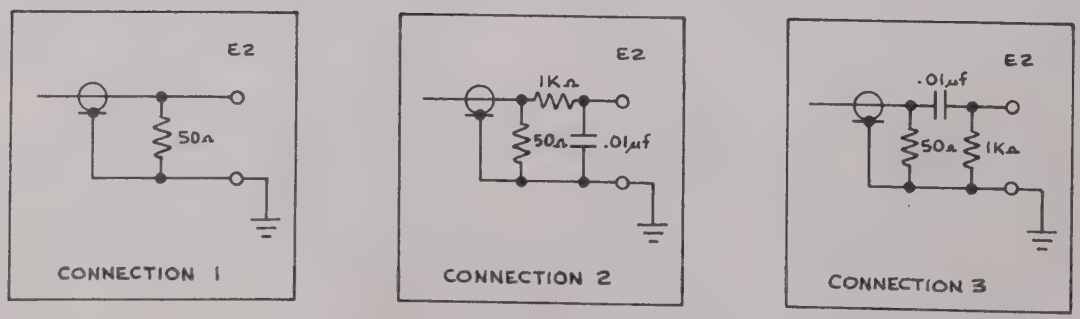
If the readings obtained in steps 1 through 9 are not within specifications, proceed with the phase calibration verification procedure given in paragraph 5-6. This procedure is also silkscreened on the rear panel of the instrument.



TEST SETUP "A"



TEST SETUP "B"



NOTE: IN TEST SETUPS "A" AND "B" 75Ω OR 600Ω COMPONENTS CAN BE USED WITH EQUAL ACCURACY. IF TERMINATIONS ARE NOT USED THE HIGH FREQUENCY ACCURACY (1-2MHz) MAY SUFFER.

Figure 5-1. Test Setups for Performance Verification and Recalibration Procedures

Table 5-2. Standard Control Settings

E1 AND E2 LEVEL SWITCHES: 1mV to 2V position.

PHASE METER RANGE SWITCH: 180° position.

0° + 180° SWITCH: 0 position.

LOW FREQ LIMIT CONTROL: 1000Hz position.

METER OFFSET: 0°, + position.

5-6. PHASE CALIBRATION VERIFICATION

1. Apply a test signal of 30mV at 1kHz to input E1 only. Short input E2 to ground. Select 1000Hz position on LOW FREQ LIMIT control. Select 1mV to 2V input level range, and adjust front panel zero control to mid-position.

2. Adjust -180° PHASE ADJ control on rear panel for -1.800V ±0.4mV on DVM (connected to PHASE OUT connector).

3. Apply test signal to input E2 and short E1 to ground. Adjust +180° PHASE ADJ control for +1.800V ±0.4mV on DVM.

4. Apply test signal to both E1 and E2. Measure voltage at PHASE OUT connector. If within ±2.5mV of zero, adjust ZERO control for 0 ±0.4mV. If reading exceeds ±2.5mV, see calibration section of the manual.

5. Adjust RANGE ZERO control on rear panel for zero reading on phase meter with PHASE METER RANGE switch at 5°.

5-7. LEVEL VARIATIONS CHECK

1. With the test equipment connected as shown in Figure 5-1, Test Setup A, and with 1kHz test frequency set the PHASE METER RANGE switch to ±5°. Adjust the front panel ZERO control for a zero reading on the panel meter.

2. Reduce the setting of the attenuator in 10 dB steps and note the phase reading. If in covering the range 0 to 60 dB, the phase readout changes greater than 1° for a 20 dB level change in both inputs, refer to paragraph 5-15 for adjustments.

5-8. FREQUENCY VARIATIONS CHECK

1. With the test equipment connected as shown in Test Setup B of Figure 5-1, set the PHASE METER RANGE switch to ±5° and the input switches to the 1mV to 2V position. Set the input level to 30mV rms on each channel at 1kHz. Adjust the ZERO control for zero reading on the meter. Check for deviation from zero at 1kHz, 100kHz, 1MHz, and 2MHz. Note phase readings. Reduce the test frequency to 100Hz, switch the LOW FREQ LIMIT control to 100Hz position. Note the phase reading. Make a similar measurement at 10Hz with the LOW FREQ LIMIT switch in the 10Hz position. The phase zero should change less than ±1° from 100Hz to 100kHz and less than ±4° from 10Hz to 2MHz.

   See paragraph 5-15 for corrective action if these readings are exceeded.

5-9. PHASE ACCURACY CHECK

1. The preceding procedure adequately covers the phase performance of the instrument. The following confidence check is included because of its simplicity and the ready availability of the

necessary components. Users having precision phase generators may use them for phase checks.

2. Use Test Setup B as modified by Connection 1 shown in Figure 5-1. Set the Test Oscillator to 1kHz, attenuator No. 1 to 30dB, and attenuator No. 2 to 20dB. Note the 50 ohm resistor across the cable providing the E2 signal. Set the ZERO control for a panel meter reading of zero degrees using the ±5° range. If more accurate readings are desired, use a precision high impedance voltmeter at the PHASE OUT connector and set it to zero rather than the panel meter.

3. Change from Connection 1 to Connection 2 using the component values indicated and short lead length to minimize pick-up of extraneous signals. Precision values are not required, but the component quality should be good, i.e., use a capacitor with Mylar or similar low loss dielectric so that its parallel shunt leakage path is negligible. Record the phase reading with this connection.

4. Change to Connection 3 and record the phase reading. The sum of the two phase readings should be 90° ±0.47° ± voltmeter tolerance when read at PHASE OUT connector or additional ±0.8° is allowable when using the METER OFFSET and 10° PHASE METER RANGE for readout.

5. If the tolerances of this phase check are not met, conduct the preceding checks of the Performance Verification Test to determine the nature of the fault and the appropriate recalibration section.

5-10. CALIBRATION PROCEDURE

The following paragraphs contain a procedure in seven parts for recalibrating the phase meter. Under normal circumstances, regularly scheduled recalibration of the phase meter will not be required. However, if the performance verification tests indicate a need for calibration, or if any of the phase meter circuit boards are replaced or repaired, the appropriate parts of the procedure should be performed. Before starting the procedures given in paragraphs 5-17 or 5-18, proceed as follows:

1. Check if a small value capacitor is connected between TP1 and TP2 on the amplifier board.

2. Remove the capacitor if present, and do not reconnect unless proper balance cannot be obtained without it (see paragraph 5-18).

5-11. STANDARD CONTROL SETTINGS

Unless otherwise stated, the standard position of front panel controls during calibration is shown in Table 5-2.

NOTE

See Figure 5-3 for location of test points and adjustments.

5-12. POWER SUPPLIES

1. +5.9V reference: Set the voltage on pin 35 to +5.9V ±20mV by placing a resistor or jumper across pins 35, 36, 37 (any combination) to increase the voltage to +5.9; or increase the value of R424 to decrease the voltage to +5.9V.

NOTE

The +5.9V reference may have been adjusted above or below the nominal value to optimize the -1.800V adjustment range. Perform the remaining power supply checks and paragraph 5-13 before changing the +5.9V reference.

2. Measure the 26 volt supply across terminals 38 and 39 with an off-ground DVM. Voltage should be 26 volts ±0.2V. If out-of-tolerance, adjust R412 for this voltage. Otherwise leave it unchanged.

3. Ripple on ±13V lines: Vary the supply voltage from 102 to 125 volts rms and measure the ac ripple across C406 and C407, using an oscilloscope. It should be less than 2mV p-p.

5-13. PHASE OUT VOLTAGE CALIBRATION

1. With front panel controls in standard positions, and using short clip leads, connect terminals 23 and 26 on PC board number 2 to ground.

2. Measure the voltage on the slider of R337 front panel ZERO control and adjust to 0 ±5mV.

3. Remove the ground connection from terminal 26.

4. Short the E2 input and apply a 1 volt rms signal at 1kHz to the E1 input.

5. Measure the voltage at the PHASE OUT connector. The reading should be -1.800V ±1mV. If necessary, set to -1.800V using R441 - 180° PHASE ADJ control.

6. Transfer the short to the E1 input, and apply the 1kHz signal to E2 input.

7. The PHASE OUT voltage should now be +1.800V ±1mV. If necessary, set to +1.800V using R434 + 180° PHASE ADJ control.

5-14. OFFSET AND METER CALIBRATION

A. OFFSET CONTROL

1. Measure the voltage at terminal 16 on board 2. The reading should be +3.4V ±10mV. If necessary, set to +3.400V ±1mV using R332 OFFSET CAL.

2. Measure the voltage at terminal 19 on board 2 with OFFSET polarity switch in the - position. Switch to +. The measured voltage should be within 2mV of - position. If not, set voltage to ±0.1mV of previously measured voltage using R334 OFFSET ZERO control.

3. Repeat steps 1 and 2 as required.

4. Remove ground from terminal 23. Check that the voltage at terminal 23 is 0 ±10mV. If not, set to 0 ±1mV using R336 OFFSET CAL control.

B. METER ZERO

1. Short the meter terminals and adjust mechanical zero. Remove short.

2. Set PHASE OUT to 0 ±1mV with front panel ZERO control. Use a Fluke DVM.

3. Meter should read zero. If not, adjust R326 METER ZERO to give zero meter reading.

4. Turn PHASE METER RANGE switch to 5° range. Meter should read zero. If necessary adjust R330 RANGE ZERO control on rear panel.

5. Repeat steps 3 and 4 as necessary, returning PHASE METER RANGE switch to 180° range.

C. METER CALIBRATION

1. Connect a 1 volt rms 1kHz signal to E1 input. Short E2 input. The meter should read -180°. Note this reading.

2. Connect the test signal to E2 input. Short E1 input. The meter should read +180°. Note this reading.

3. Adjust METER CAL R325, if necessary, to minimize METER symmetry error.

4. Connect terminal 26 on board 2 to ground.

5. Set PHASE METER RANGE switch to 10° position. Be sure meter reads 0 (if necessary, adjust using RANGE ZERO R330).

6. Set in 10° offset. Switching polarity + to -, adjust RANGE TRACKING R323 to minimize meter error.

7. Use the METER OFFSET control to check the meter accuracy in +10° steps on each position of the PHASE METER RANGE switch. Switch the OFFSET POLARITY to negative and check each position of the PHASE METER RANGE switch.

5-15. AMPLIFIER CIRCUIT ADJUSTMENTS

1. Disconnect the oscillator and the voltmeter from the phase meter. Connect BNC type shorting connectors to the E1 and E2 input connectors.

   Set the DVM for differential operation. Connect the voltmeter between test points TP1 and TP2 on the E1 amplifier circuit card 350-1 via two 100K ohm resistors (one on each lead). The voltmeter reading should be 0V (±1mV). If not, adjust R111 on the E1 amplifier circuit card to obtain the correct value.

2. Connect the voltmeter between test points TP3 and TP4 via the 100K ohm resistors. Connect a shorting jumper between test points TP1 and TP2. The voltmeter reading should be 0V (±1mV). If not, adjust R122 to obtain the correct value.

3. Connect the voltmeter between test points TP5 and TP6 via the 100K ohm resistors. Transfer the shorting jumper from TP1 - TP2 to TP3 - TP4. The voltmeter reading should be 0V (±1mV). If not, adjust R137 to obtain the correct reading.

4. Connect the voltmeter between test points TP7 and TP8 via the 100K ohm resistors. Transfer the shorting jumper to TP5 - TP6. The voltmeter reading should be 0V (±10mV). If not, adjust R150 to obtain the correct value.

5. Repeat the procedure using the corresponding test points and adjustments on the E2 amplifier circuit card.

6.

   a. Insert 1V rms signal at 1kHz to both E1 and E2 inputs. Observe PHASE OUT signal at front panel with an oscilloscope set for 5mV/cm and 2 msec/cm sweep speed.

   b. Adjust ripple adjust control R314 on 350-2B P.C. board for 1mV p-p of ripple, maximum.

   c. Maintaining 1V rms input level, insert the appropriate frequency for each position of the smoothing filter. (100Hz, 30Hz, 10Hz). Ripple at the PHASE OUT connector should be no greater than 2mV p-p in each case.

5-16. TRIGGER CIRCUIT ADJUSTMENTS

A. OVERSHOOT ADJUST

1. Apply a 600kHz 1 volt rms signal to E1 and E2 inputs. Connect an oscilloscope via a 1ρF capacitor and a 10 to 1 compensated probe to TP9. Adjust C111 for equal positive and negative overshoot on the leading and trailing edge of the square wave.

2. Repeat this procedure on the E2 amplifier using TP10 and C111 on E2 amplifier board.

B. TRIGGER BIAS ADJUST

1. With a 1kHz test signal applied to E1 and E2 inputs, attenuate each 30dB and adjust ZERO control for zero meter reading in 5° range.

2. Attenuate E1 60dB and if necessary adjust R204 TRIGGER BIAS ADJ NO. 1 to bring meter back to zero. Vary attenuator in 10dB steps from 0 to 60dB noting that the average meter reading varies less than 0.2° from 0 to 40dB and less than 0.4° from 40 to 60dB.

3. Repeat step 2 on E2 amplifier, making adjustment with R219 TRIGGER BIAS ADJ NO. 2.

C. RISE/FALL TIME ADJUSTMENTS

With 600kHz at 1 volt rms (at 0dB attenuation) input to each amplifier, connect the oscilloscope via a 3.3ρF capacitor and 10 to 1 compensated probe to TP13. Set sweeptime at 0.1μsec, sweep magnified X 20. Adjust C303 for equal rise and fall time between 10% and 90% levels.

NOTE

It may be necessary to compromise the 10% and 90% levels and the zero crossing point to equalize truly. Check that in varying both the attenuators at the same time from 30 to 0 dB the meter does not change more than 1.5° from zero.

5-17. ATTENUATOR COMPENSATION ADJUSTMENT

A. E1 ATTENUATOR

1. Apply 1 volt rms to E1 and E2 inputs at 100kHz. Attenuate E1 and E2 40dB. Zero the meter on the 5° range.

2. Remove the 40dB attenuation and switch the E1 attenuator to the 200mV to 400 V range. Adjust C162 on the attenuator switch to return the meter reading to 0°.

B. E2 ATTENUATOR

Repeat the above steps using the E2 attenuator and the corresponding C162 trimmer on E2.

5-18. AMPLIFIER COMPENSATION

With 1kHz at 1 volt rms to attenuators set in 30dB attenuation, zero meter on ±5° scale using ZERO control. Change input frequency to 2.0MHz. The meter should read 0 ±0.5° on 5° range. If necessary, use a small capacitor between TP1 and TP2 on E2 (or E1, depending on which side of zero the meter reads) to bring meter reading to zero. Typical values would be in the range of 0.68 - 3.3ρF.

5-19. TROUBLESHOOTING

When a malfunction is noted during operation of the phase meter, the operator should first perform the installation and operation procedures in Sections II and III to discover any obvious faults. The performance verification and recalibration procedures can then be used to attempt to isolate the malfunction to a particular circuit. The exact cause of the malfunction can next be located by circuit analysis and conventional test methods such as signal tracing, voltage and resistance measurements, and component substitutions.

When troubleshooting, refer to the schematic diagrams in Section VII, the principles of operation discussion and simplified schematic diagrams in Section IV. Use the performance verification guides. Be familiar with the operating precautions and other information in Section III to avoid problems which appear to be in the phase meter but actually are external faults associated with signal interference or improper test equipment interconnections.

Useful test voltages and waveforms are shown on the schematic diagrams in Section VII and the simplified schematic diagrams in Section IV. Although these waveforms are typical and idealized, observation of the waveform at the test points will indicate whether or not the signal circuits up to that point are functioning or not.

5-20. CIRCUIT BOARD LOCATION AND ARRANGEMENT

The main sections of the instrument are the two identical signal amplifier boards (input boards), the board containing the trigger generators, phase detector multivibrator, error sector detector and meter amplifiers (output board), and the power supply. Figure 5-3 shows these subassemblies as viewed from the underside of the cabinet.

5-21. TROUBLESHOOTING PROCEDURE

The two basic types of trouble which can be encountered with this instrument are non-operation and apparent error. Locating and correcting non-operation is relatively straightforward. Careful observation of the effect should enable the isolation of the cause to a particular section or location. Troubleshooting for apparent error is likely to involve making adjustments and require going through a part of all of a recalibration procedure.

5-22. NON-OPERATION

Non-operation troubles divide essentially into those involving lack of power and those involving failure to process signals. If the unit fails to turn on, check the following in sequence. (See Figure 2-2.)

1. Input power source.
2. Fuse.
3. Voltage Switch Selector S402.
4. Ac voltage at primary and secondary of power transformer T401.

If the unit turns on but appears completely inoperative, check the dc output voltages at terminals 2 and 5 on the power supply chassis.

5-23. TEST VOLTAGES AND WAVEFORMS

Useful test voltages are shown on the schematic drawings. Waveform amplitudes are shown on the simplified schematic drawings. (See Figures 4-4 through 4-8).

5-24. SIGNAL TRACING

Troubleshooting a failure of the unit to process signals is best accomplished by applying a common input signal to the E1 and E2 inputs and then tracing them through the signal paths by the oscilloscope observation at each test point. The simplified schematic diagrams in Section IV are well suited for waveform comparison. Waveforms observed in this manner, although not ideal in shape like the qualitive sketches on the simplified schematics, will be close enough to indicate whether the signal circuits up to the observed point are or are not functioning. A fault in one channel can be diagnosed by waveform and voltage comparisons with the good channel.

5-25. METER AMPLIFIER CIRCUIT

Trouble in the meter amplifiers can be quickly isolated by making a check of the voltage at the PHASE OUT connector with input signal applied. If the PHASE OUT voltage is normal and the meter does not read or does not agree, the trouble is in the meter amplifier section.

5-26. JUMPY READINGS

Jumpy readings are usually caused by ac power line noise getting into the test setup. See paragraph 3-3, PRECAUTIONS TO TAKE FOR STABLE PHASE ANGLE MEASUREMENTS.

SECTION VI
REPLACEABLE PARTS

6-1. INTRODUCTION

This section of the manual contains alphanumeric listings of the replaceable component parts available for a Model 350 Phase Meter. These listings, as shown in Table 6-1, are arranged by component type, i.e. Resistors, Capacitors, etc.

Table	Title	Page
6-2	Resistors	6-2
6-3	Capacitors	6-4
6-4	Inductors	6-6
6-5	Transistors	6-6
6-6	Diodes	6-7/6-8
6-7	Switches	6-7/6-8
6-8	Miscellaneous	6-7/6-8

Given in each listing is the reference designation, complete part description, and WILTRON part number for each item used in the manufacture of a unit. Items such as machined parts, hardware, etc. are not included although they may be ordered through us upon special request.

6-2. ORDERING REPLACEABLE PARTS

Replacement parts for a Model 350 Phase Meter may be ordered through your local WILTRON representative, or directly from:

WILTRON Company
825 East Middlefield Road
Mountain View, CA 94043

Telephone: (415) 969-6500

When placing your order, give our representative complete information regarding the part required including the model and serial number of the instrument in which the part is to be used, reference designation, full part description, WILTRON part number, and the total quantity desired. We will endeavor to provide you with the latest, most improved components as they become available.

Table 6-2. Resistors

REF. DES.	DESCRIPTION	WILTRON PART NO.
R101	1K, 1/4W, 5%, CC	101-1K-5
R102	1K, 1/4W, 5%, CC	101-1K-5
R103	13K, 1/4W, 5%, CC	101-13K-5
R104	20K, 1/4W, 5%, CC	101-20K-5
R105	6.8K, 1/4W, 5%, CC	101-6.8K-5
R106	1.18K, 1/4W, 1%, MF	110-1.18K-1
R107	240, 1/4W, 5%, CC	101-240-5
R108	1.5K, 1/4W, 1%, MF	110-1.5K-1
R109	13K, 1/4W, 5%, CC	101-13K-5
R110	30K, 1/4W, 5%, CC	101-30K-5
R111	100, potentiometer	141-100
R112	1.18K, 1/4W, 1%, MF	110-1.18K-1
R113	240, 1/4W, 5%, CC	101-240-5
R114	1.5K, 1/4W, 1%, MF	110-1.5K-1
R115	6.8K, 1/4W, 5%, CC	101-6.8K-5
R116	20K, 1/4W, 5%, CC	101-20K-5
R117	6.8K, 1/4W, 5%, CC	101-6.8K-5
R118	82, 1/4W, 5%, CC	101-82-5
R119	1K, 1/4W, 1%, MF	110-1K-1
R120	100, 1/4W, 5%, CC	101-100-5
R121	649, 1/4W, 1%, MF	110-649-1
R122	100, potentiometer	141-100
R123	24K, 1/4W, 5%, CC	101-24K-5
R124	8.2K, 1/4W, 5%, CC	101-8.2K-5
R125	1K, 1/4W, 1%, MF	110-1K-1
R126	100, 1/4W, 5%, CC	101-100-5
R127	649, 1/4W, 1%, MF	110-649-1
R128	6.8K, 1/4W, 5%, CC	101-6.8K-5
R129	82, 1/4W, 5%, CC	101-82-5
R130	82, 1/4W, 5%, CC	101-82-5
R131	6.8K, 1/4W, 5%, CC	101-6.8K-5
R132	649, 1/4W, 1%, MF	110-649-1
R133	100, 1/4W, 5%, CC	101-100-5
R134	1K, 1/4W, 1%, MF	110-1K-1
R135	8.2K, 1/4W, 5%, CC	101-8.2K-5
R136	24K, 1/4W, 5%, CC	101-24K-5
R137	100, potentiometer	141-100
R138	649, 1/4W, 1%, MF	110-649-1
R139	100, 1/4W, 5%, CC	101-100-5
R140	1K, 1/4W, 1%, MF	110-1K-1

Table 6-2. Resistors (cont)

REF. DES.	DESCRIPTION	WILTRON PART NO.
R141	82, 1/4W, 5%, CC	110-82-5
R142	6.8K, 1/4W, 5%, CC	101-6.8K-5
R143	3.9K, 1/4W, 5%, CC	101-3.9K-5
R144	82, 1/4W, 5%, CC	101-82-5
R145	1K, 1/4W, 1%, MF	110-1K-1
R146	100, 1/4W, 5%, CC	101-100-5
R147	24K, 1/4W, 5%, CC	101-24K-5
R148	8.2K, 1/4W, 5%, CC	101-8.2K-5
R149	432, 1/4W, 1%, MF	110-432-1
R150	100, potentiometer	141-100
R151	1K, 1/4W, 1%, MF	110-1K-1
R152	100, 1/4W, 5%, CC	101-100-5
R153	3.9K, 1/4W, 5%, CC	101-3.9K-5
R154	82, 1/4W, 5%, CC	101-82-5
R155	1K, 1/4W, 5%, CC	101-1K-5
R156	100, 1/4W, 5%, CC	101-100-5
R157	100, 1/4W, 5%, CC	101-100-5
R158	100, 1/4W, 5%, CC	101-100-5
R159	-- not used --	
R160	-- not used --	
R161	1M, 1/2W, 1%, MF	112-1M-1
R162	4.99K, 1/2W, 1%, MF	112-4.99K-1
R163 thru R200	-- not used --	
R201	8.2K, 1/4W, 5%, CC	101-8.2K-5
R202	2.7K, 1/4W, 5%, CC	101-2.7K-5
R203	27K, 1/4W, 5%, CC	101-27K-5
R204	5K, potentiometer	141-5K
R205	20K, 1/4W, 5%, CC	101-20K-5
R206	20K, 1/4W, 5%, CC	101-20K-5
R207	1.62K, 1/8W, 1%, MF	110-1.62K-1
R208	3.92K, 1/8W, 1%, MF	110-3.92K-1
R209	10K, 1/8W, 1%, MF	110-10K-1
R210	11K, 1/8W, 1%, MF	110-11K-1
R211	2.7K, 1/4W, 5%, CC	101-2.7K-5
R212	100, 1/4W, 5%, CC	101-100-5
R213	4.7K, 1/4W, 5%, CC	101-4.7K-5
R214	100, 1/4W, 5%, CC	101-100-5
R215	100, 1/4W, 5%, CC	101-100-5

Table 6-2. Resistors (cont)

REF. DES.	DESCRIPTION	WILTRON PART NO.
R216	8.2K, 1/4W, 5%, CC	101-8.2K-5
R217	2.7K, 1/4W, 5%, CC	101-2.7K-5
R218	27K, 1/4W, 5%, CC	101-27K-5
R219	5K, potentiometer	141-5K
R220	20K, 1/4W, 5%, CC	101-2-K-5
R221	20K, 1/4W, 5%, CC	101-20K-5
R222	1.62K, 1/8W, 1%, MF	110-1.62K-1
R223	3.92K, 1/8W, 1%, MF	110-3.92K-1
R224	10K, 1/8W, 1%, MF	110-10K-1
R225	11K, 1/8W, 1%, MF	110-11K-1
R226	2.7K, 1/4W, 5%, CC	101-2.7K-5
R227	100, 1/4W, 5%, CC	101-100-5
R228	4.7K, 1/4W, 5%, CC	101-4.7K-5
R229	100, 1/4W, 5%, CC	101-100-5
R230	100, 1/4W, 5%, CC	101-100-5
R231	10K, 1/4W, 5%, CC	101-10K-5
R232	10K, 1/4W, 5%, CC	101-10K-5
R233	2.2K, 1/4W, 5%, CC	101-2.2K-5
R234	2.2K, 1/4W, 5%, CC	101-2.2K-5
R235	47K, 1/4W, 5%, CC	101-47K-5
R236	3.3K, 1/4W, 5%, CC	101-3.3K-5
R237	10K, 1/4W, 5%, CC	101-10K-5
R238	2.7K, 1/4W, 5%, CC	101-2.7K-5
R239	4.7K, 1/4W, 5%, CC	101-4.7K-5
R240	10K, 1/4W, 5%, CC	101-10K-5
R241	47K, 1/4W, 5%, CC	101-47K-5
R242	47K, 1/4W, 5%, CC	101-47K-5
R243	10K, 1/4W, 5%, CC	101-10K-5
R244	4.7K, 1/4W, 5%, CC	101-4.7K-5
R245	10K, 1/4W, 5%, CC	101-10K-5
R301	499, 1/2W, 1%, MF	112-499-1
R302	8.2K, 1/4W, 5%, CC	101-8.2K-5
R303	3.3K, 1/4W, 5%, CC	101-3.3K-5
R304	130, 1/2W, 5%, CC	102-130-5
R305	1K, 1/4W, 5%, CC	101-1K-5
R306	11K, 1/4W, 5%, CC	101-11K-5
R307	1K, 1/4W, 5%, CC	101-11K-5
R308	8.2K, 1/4W, 5%, CC	101-8.2K-5
R309	3.3K, 1/4W, 5%, CC	101-3.3K-5
R310	499, 1/2W, 1%, MF	112-499-1

Table 6-2. Resistors (cont)

REF. DES.	DESCRIPTION	WILTRON PART NO.
R311	330, 1/2W, 5%, CC	101-330-5
R302	8.2K, 1/4W, 5%, CC	101-8.2K-5
R313	2.2K, 1/4W, 5%, CC	101-2.2K-5
R314	5K, potentiometer	141-5K
R315	5.867K, 1/4W, 0.1%, WW	130-5.867K-0.1
R316	820, 1/2W, 5%, CC	102-820-5
R317	10K, 1/4W, 5%, CC	101-10K-5
R320	130, 1/4W, 5%, CC	101-130-5
R321	12K, 1/4W, 5%, CC	101-12K-5
R322	6.00K, 1/4W, 0.1%, WW	130-6.00K-0.1
R323	100, potentiometer	141-100
R324	3.3K, 1/4W, 5%, CC	101-3.3K-5
R325	5K, potentiometer	141-5K
R326	500, potentiometer	141-500
R327	100, 1/4W, 5%, CC	101-100-5
R328	3,3K, 1/4W, 5%, CC	101-3.3K-5
R329	6.00K, 1/4W, 0.1%, WW	130-6.00K-0.1
R330	500, potentiometer	152-500
R331	12K, 1/4W, 5%, CC	101-12K-5
R332	500, potentiometer	141-5K
R333	1.37K, 1/8W, 1%, MF	110-1.37K-1
R334	100, potentiometer	141-100
R335	1.37K, 1/8W, 1%, MF	110-1.37K-1
R336	500, potentiometer	141-500
R337	500K, potentiometer	141-500K
R338	110K, 1/4W, 5%, CC	101-110K-5
R339	3.30K, 1/8W, 1%, MF	110-3.30K-1
R340	3.30K, 1/8W, 1%, MF	110-3.30K-1
R341	14226, 1/4W, 0.1%, WW	130-14.226K-0.1
R342	5123, 1/4W, 0.1%, WW	130-5.123K-0.1
R343	2068, 1/4W, 0.1%, WW	130-2.068-0.1
R344	625.2, 1/4W, 0.1%, WW	130-625.2-0.1
R345	309.5, 1/4W, 0.1%, WW	130-309.5-0.1
R346	120.1, 1/4W, 0.1%, WW	130-120.1-0.1
R347	thru R363 100 matched set 1%, MF	113-100-0.1 (T2)

Table 6-2. Resistors (cont)

REF. DES.	DESCRIPTION	WILTRON PART NO.
R364	1.74K, 1/8W, 1%, MF	110-1.74K-1
R365	470, 1/4W, 5%, CC	101-470-5
R401	1.0, 3W, 5%, WW	130-1-3
R402	5.6K, 1/4W, 5%, CC	101-5.6K-5
R403	3.6K, 1/4W, 5%, CC	101-3.6K-5
R404	1.0, 1/2W, 5%, CC	102-1-5
R405	10, 1/4W, 5%, CC	101-10-5
R406	6.8K, 1/4W, 5%, CC	101-6.8K-5
R407	20K, 1/4W, 5%, CC	101-20K-5
R408	3.01K, 1/8W, 1%, MF	110-3.01K-1
R409	12.70K, 1/8W, 1%, MF	110-12.70k-1
R410	24K, 1/4W, 5%, CC	101-24K-5
R411	2.0K, 1/8W, 1%, MF	110-2.00K-1
R412	250, potentiometer	141-250
R413	2.21K, 1/8W, 1%, MF	110-2.21K-1
R414	62K, 1/4W, 5%, CC	101-62K-5
R415	20K, 1/8W, 1%, MF	110-20.0K-1
R416	20K, 1/8W, 1%, MF	110-20.0K-1
R417	47K, 1/4W, 5%, CC	101-47K-5
R418	240K, 1/4W, 5%, CC	101-240K-5
R419	10K, 1/4W, 5%, CC	101-10K-5
R420	7.5K, 1/4W, 5%, CC	101-7.5K-5
R421	1K, 1/4W, 5%, CC	101-1K-5
R422	430, 1/2W, 5%, CC	102-430-5
R423	430, 1/2W, 5%, CC	102-430-5
R424	28.7, 1/8W, 1%, MF	110-28.7-1
R425	56.2, 1/8W, 1%, MF	110-56.2-1
R426	866, 1/8W, 1%, MF	110-866-1
R427	464, 1/8W, 1%, MF	110-464-1
R428	1.3K, 1/4W, 5%, CC	101-1.3K-5
R429	100K, 1/4W, 5%, CC	101-100K-5
R430	91K, 1/4W, 5%, CC	101-91K-5
R431	100K, 1/4W, 5%, CC	101-100K-5
R432	200, 1/4W, 5%, CC	101-200-5
R433	1K, 1/8W, 1%, MF	110-1K-1
R434	500, potentiometer	152-500
R435	9.31K, 1/8W, 1%, MF	110-9.31K-1
R436	100K, 1/4W, 5%, CC	101-100K-5
R437	1K, 1/4W, 5%, CC	101-1K-5
R438	12K, 1/4W, 5%, CC	101-12K-5

Table 6-2. Resistors (cont)

REF. DES.	DESCRIPTION	WILTRON PART NO.
R439	130, 1/2W, 5%, CC	102-130-5
R440	9.24K, 1/4W, 0.1%, WW	130-9.24K-0.1
R441	500, potentiometer	152-500
R442	11.12K, 1/4W, 0.1%, WW	130-11
R443	16K, 1/4W, 5%, CC	101-16K-5
R444	200, 1/4W, 5%, CC	101-200-5
R445	30K, 1/4W, 5%, CC	101-30K-5
R446	16K, 1/4W, 5%, CC	101-16K-5
R447	5.1K, 1/4W, 5%, CC	101-5.1K-5
R448	330, 1/4W, 5%, CC	101-330-5
R449	3.6K, 1/4W, 5%, CC	101-3.6K-5
R450	100, 1/2W, 5%, CC	102-100-5
R451	3K, 1/4W, 5%, CC	101-3K-5
R452 thru R460	-- not used --	
R461	22, 1/4W, 5%, CC	101-22-5

(1) CC = Carbon Composition
MF = Metal Film
WW = Wire Wound

Table 6-3. Capacitors

REF. DES.	DESCRIPTION	WILTRON PART NO.
C101	1μF, 20V, 10%, MY	210-36
C102	80μF, 25V, --, E	250-22
C103	39μF, 10V, 20%,	250-27
C104	-- not used --	
C105	500μF, 15V, --, E	250-16
C106	39μF, 10V, 20%, T	250-27
C107	39ρF, 500V, 5%, Mi	220-39
C108	1000μF, 15V, --, E	250-28
C109	1000μF, 15V, --, E	250-28
C110	39ρF, 500V, 5%, Mi	220-39

Table 6-3. Capacitors (cont)

REF. DES.	DESCRIPTION	WILTRON PART NO.
C111	5-60ρF Variable	240-11
C112	.1μF, 250V, 20%, My	210-30
C113	.1μF, 250V, 20%, My	210-30
C114	20ρF, 500V, 5%, Mi	220-20
C115	15ρF, 500V, 5%, My	220-15
C116	.1μF, 250V, 2%, My	210-30
C117 thru C160	-- not used --	
C161	.22μF, 400V, 10%, My	210-37
C162	2-25ρF, variable	240-29
C163	1300ρF, 500V, 5%, Mi	225-1300
*C164	8.2ρF, 500V, 5%, Mi	220-8
C165	1.0μF, 35V, 10%, T	250-19
C166	80μF, 25V, --, E	250-22
C167	0.1μF, 250V, 10%, My	210-30
C201	80μF, 25V, --, E	250-22
C202	2-18ρF, variable	240-12
*C203	15ρF, 500V, 5%, Mi	220-15
C204	15ρF, 500V, 5%, Mi	220-15
C205	32μF, 64V, --, E	250-7
C206	32μF, 64V, --, E	250-7
C207	80μF, 25V, --, E	250-22
C208	2-18ρF, variable	240-12
*C209	15ρF, 500V, 5%, Mi	220-15
C210	15ρF, 500V, 5%, Mi	220-15
C211	32μF, 64V, --, E	250-7
C212	32μF, 64V, --, E	250-7
C213	.047μF, 250V, 10%, My	210-28
C214	.047μF, 250V, 10%, My	210-28
C215	39ρF, 500V, 5%, Mi	220-39
C216	39ρF, 500V, 5%, Mi	220-39
C217	.047μF, 250V, 10%, My	210-28
C218	.47μF, 250V, 20%, My	210-32
C219	43ρF, 500V, 5%, Mi	220-43
C220	32μF, 64V, --, E	250-7
C301	56ρF, 500V, 5%, Mi	220-56
C302	56ρF, 500V, 5%, Mi	220-56
C303	2-18ρF, variable	240-12
C304	80μF, 25V, --, E	250-22
C305	80μF, 25V, --, E	250-22

Table 6-3. Capacitors (cont)

REF. DES.	DESCRIPTION	WILTRON PART NO.
C306	10ρF, 500V, 5%, Mi	220-10
C307	80μF, 25V, --, E	250-22
C308	1.0μF, 250V, 10%, My	210-36
C309	3.3μF, 35V, --, E	250-26
C310	.001μF, 1KV, 10%, C	230-3
C311	.001μF, 1KV, 10%, C	230-3
C312	0.47μF, 250V, 20%, My	210-32
C313	250μF, 25V, --, E	250-31
C314	32μF, 64V, --, E	250-7
C315	400μF, 25V, --, E	250-30
C316	80μF, 25V, --, E	250-22
C317	32μF, 64V, --, E	250-7
C318	500μF, 15V, --, E	250-16
C401	.02μF, 500V, 20%, C	230-8
C402	.02μF, 500V, 20%, C	230-8
C403	1000μF, 50V, --, E	250-15
C404	6.8μF, 35V, 10%, T	250-41
C405	4.7μF, 10V, 20%, T	250-39
C406	250μF, 50V, --, E	250-31
C407	250μF, 50V, --, E	250-31
C408	4.7μF, 10V, 20%, T	250-39
C409	.001μF, 1KV, 10%, C	230-3
C410	4.7μF, 10V, 20%, T	250-39
C411	4.7μF, 10V, 20%, T	250-39
C412	4.7μF, 10V, 20%, T	250-39
C413	.001μF, 1KV, 10%, C	230-3
C414	4.7μF, 10V, 20%, T	250-39

*Factory selected value

(2) C = Ceramic
E = Electrolytic
Mi = Mica
My = Mylar
T = Tantalum

Table 6-4. Inductors

REF. DES.	DESCRIPTION	WILTRON PART NO.
L201	100μH	310-1
L202	100μH	310-1
L301	10μH	310-7
L302	10μH	310-7

Table 6-5. Transistors

REF. DES.	DESCRIPTION	WILTRON PART NO.
Q101	2N5248	20-2N5248
Q102*	2N4249	20-2N4249
Q103*	2N4249	20-2N4249
Q104	2N4250	20-2N4250
Q105	2N4250	20-2N4250
Q106*	2N4249	20-2N4249
Q107*	2N4249	20-2N4249
Q108	2N3565	20-2N3565
Q109	2N3565	20-2N3565
Q110	2N3565	20-2N3565
Q111	2N3565	20-2N3565
Q112	2N3565	20-2N3565
Q113	2N3565	20-2N3565
Q114*	2N4249	20-2N4249
Q115*	2N4249	20-2N4249
Q116*	2N4249	20-2N4249
Q117*	2N4249	20-2N4249
Q118*	2N4249	20-2N4249
Q119*	2N4249	20-2N4249
Q120	2N3646	20-2N3646
Q121	2N3646	20-2N3646
Q122	2N3565	20-2N3565
Q123	2N3565	20-2N3565
Q124	2N3565	20-2N3565
Q201	2N3563	20-2N3563
Q202	2N3563	20-2N3563
Q203	2N3646	20-2N3646
Q204	2N3563	20-2N3563
Q205	2N3563	20-2N3563
Q206	2N3646	20-2N3646

Table 6-5. Transistors (cont)

REF. DES.	DESCRIPTION	WILTRON PART NO.
Q207	2N3646	20-2N3646
Q208	2N3646	20-2N3646
Q209	2N3646	20-2N3646
Q210	2N3566	20-2N3566
Q301	2N3646	20-2N3646
Q302	2N3646	20-2N3646
Q303 thru Q306	2N3565	20-2N3565
Q307	2N3646	20-2N3646
Q401	2N3055	20-2N3055
Q402	2N4249	20-2N4249
Q403	2N3566	20-2N3566
Q404	2N3566	20-2N3566
Q405	2N3565	20-2N3565
Q406	2N3565	20-2N3565
Q407	2N3565	20-2N3565
Q408	2N4249	20-2N4249
Q409	2N2218	20-2N2218
Q410	2N2905	20-2N2905
Q411	TD-100	20-TD-100
Q412	2N4249	20-2N4249
Q413	2N3566	20-2N3566
Q414	TD-100	20-TD-100
Q415	2N4249	20-2N4249
Q416	2N3566	20-2N3566

NOTE:
*Instrument may be equipped with 2N5086 transistor instead of 2N4249.

Table 6-6. Diodes

REF. DES.	DESCRIPTION	WILTRON PART NO.
CR101	1N4446	10-1N4446
CR102	1N4446	10-1N4446
CR103 and CR104	Matched pair for voltage drop	350-S-808
CR105 and CR106	Matched pair for voltage drop	350-S-808
CR107 and CR108	Matched pair for voltage drop	350-S-808
CR109 thru CR200	-- not used --	---
CR201	1N4446	10-1N4446
CR202	1N4446	10-1N4446
CR203	1N4446	10-1N4446
CR204	1N4446	10-1N4446
CR205	1N4446	10-1N4446
CR206	-- not used --	---
CR207	1N4446	10-1N4446
CR208	1N4446	10-1N4446
CR301	FDH666	10-FDH666
CR302	FDH666	10-FDH666
CR303	FDH666	10-FDH666
CR304	1N4446	10-1N4446
CR305	1N4446	10-1N4446
CR306	1N4446	10-1N4446
CR307	1N4446	10-1N4446
CR308	1N4446	10-1N4446
CR401	1N4383	10-1N4383
CR402	1N4383	10-1N4383
CR403	1N4383	10-1N4383
CR404	1N4383	10-1N4383

Table 6-6. Diodes (cont)

REF. DES.	DESCRIPTION	WILTRON PART NO.
CR405	1N4446	10-1N4446
CR506	1N4446	10-1N4446
CR507	1N4446	10-1N4446
CR408	1N4446	10-1N4446
CR409	1N4446	10-1N4446
CR410	1N4446	10-1N4446
CR411	1N823	10-1N823
CR412	-- not used --	---
CR413	-- not used --	---
CR414	1N3491R	10-1N3491R
CR415	1N3491	10-1N3491

Table 6-7. Switches

REF. DES.	DESCRIPTION	WILTRON PART NO.
S101	DPDT	420-3
S201	Rotary	410-43
S301	Rotary	410-31
S302	Rotary	410-44
S303	Rotary	410-28
S304	Rotary	410-28
S401	SPST	420-1
S402	DPDT	430-9

Table 6-8. Miscellaneous

REF. DES.	DESCRIPTION	WILTRON PART NO.
DS201	Lamp, amber (ERROR SECTOR light)	632-13
DS401	Lamp, red (POWER)	632-10
F401	0.3A slo-blo fuse	631-7
M301	Meter, ±500μA	350-S-733
P401	Power cord	800-21
T401	Transformer, power	320-20

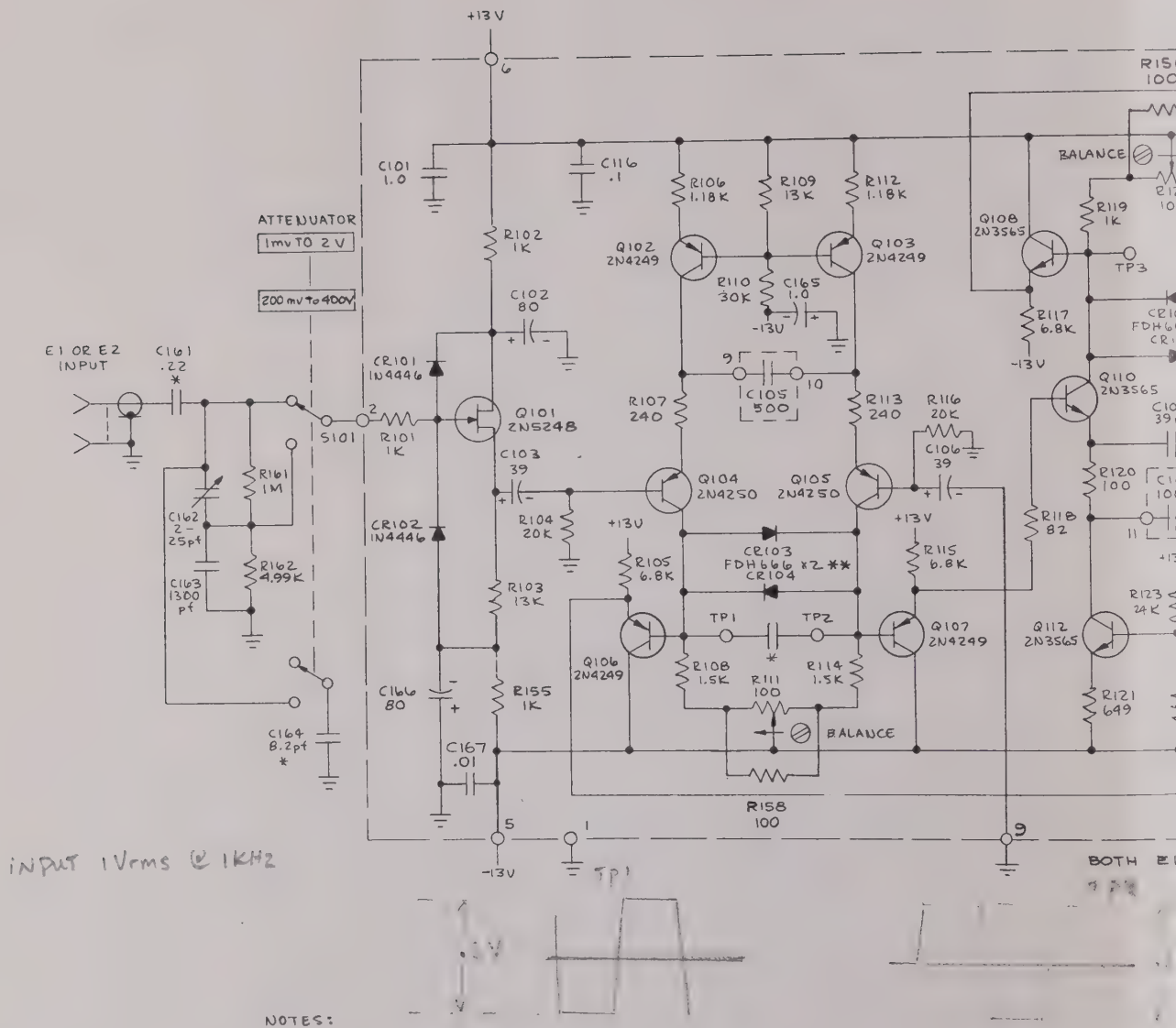
SECTION VII
SCHEMATIC DIAGRAMS

7-1. INTRODUCTION

This section of the manual contains the schematic diagrams for a Model 350 Phase Meter. Table 7-1 lists those drawings included in this section.

Table 7-1. List of Schematic Diagrams

Figure	Title	Page
7-1	Amplifiers and Limiters	7-3/7-4
7-2	Trigger Circuits and Error Detector	7-5/7-6
7-3	Phase Detector and Readout	7-7/7-8
7-4	Power Supply and Regulator	7-9/7-10

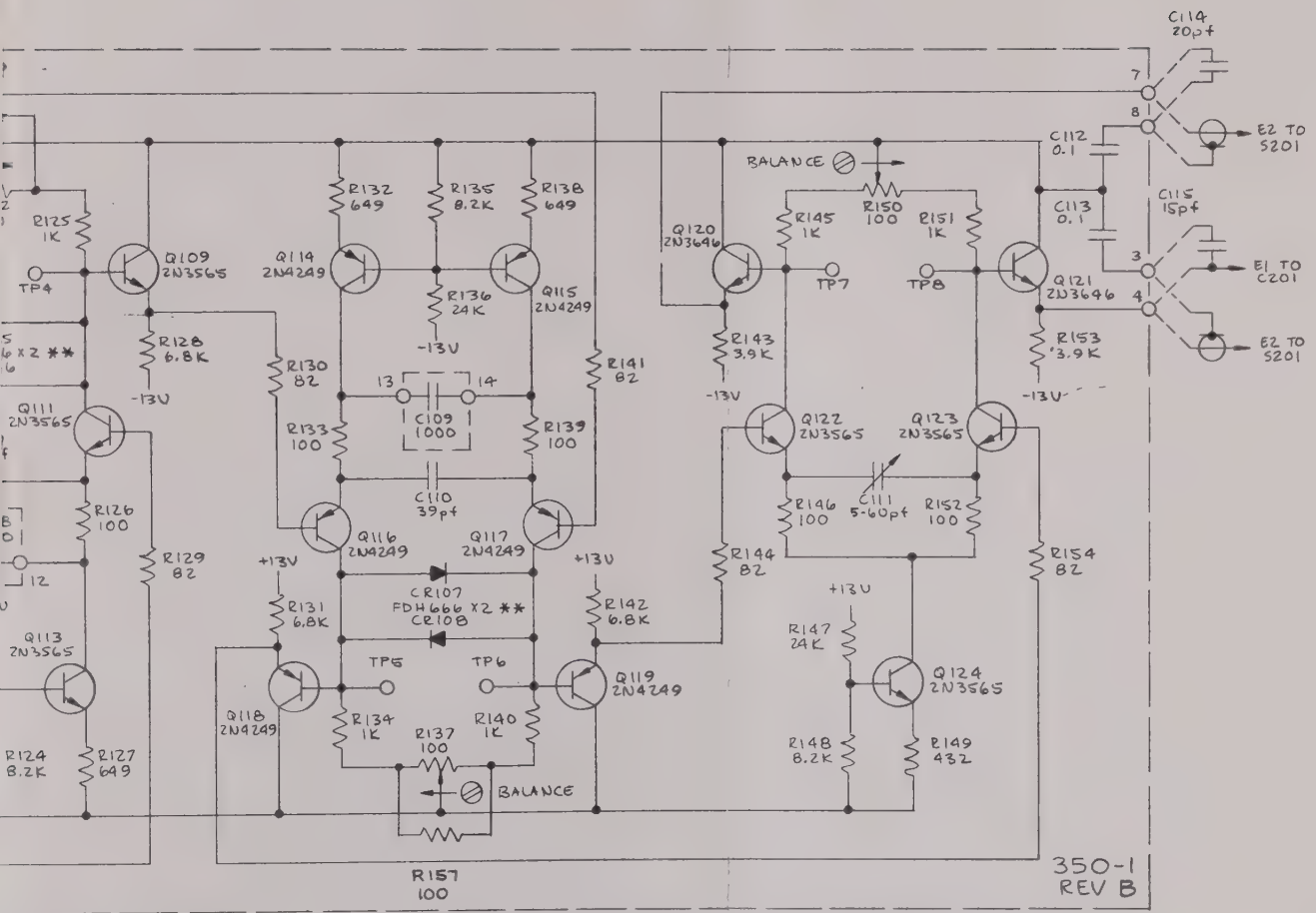


NOTES:

1. UNLESS OTHERWISE NOTED:
   RESISTANCE IN OHMS.
   CAPACITANCE IN MICROFARADS.
   * FACTORY SELECTED VALUE.

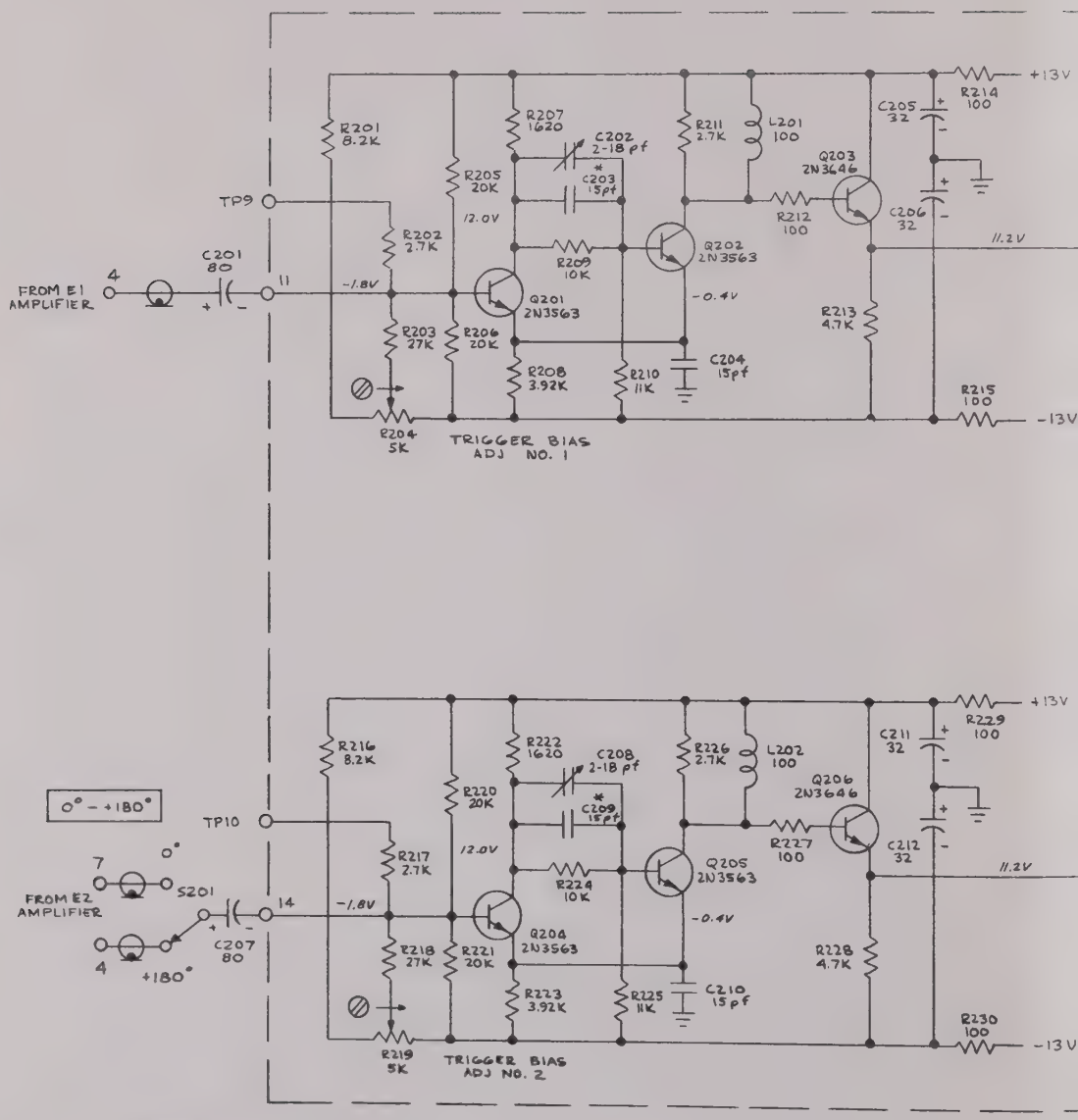
2.

3. ** CR103 - CR104, CR105 - CR106, CR107 - CR108 ARE MATCHED PAIRS FOR VOLTAGE DROP AS PER WILTRON 350-5-808.



AND E2 AMPLIFIERS HAVE THIS SAME CIRCUIT WITH DIFFERENT OUTPUT CONNECTIONS AS SHOWN

Figure 7-1. Amplifiers and Limiters



NOTES:

1. UNLESS OTHERWISE NOTED:
   RESISTANCE IN OHMS
   CAPACITANCE IN MICROFARADS
   INDUCTANCE IN MICROHENRIES
   * FACTORY SELECTED VALUE

2. VOLTAGES MEASURED WITH 1 VOLT rms INPUT TO EACH CHANNEL. S101 IN 200mv TO 400V POSITION. VOLTMETER WITH 100 MΩ IMPEDANCE USED.

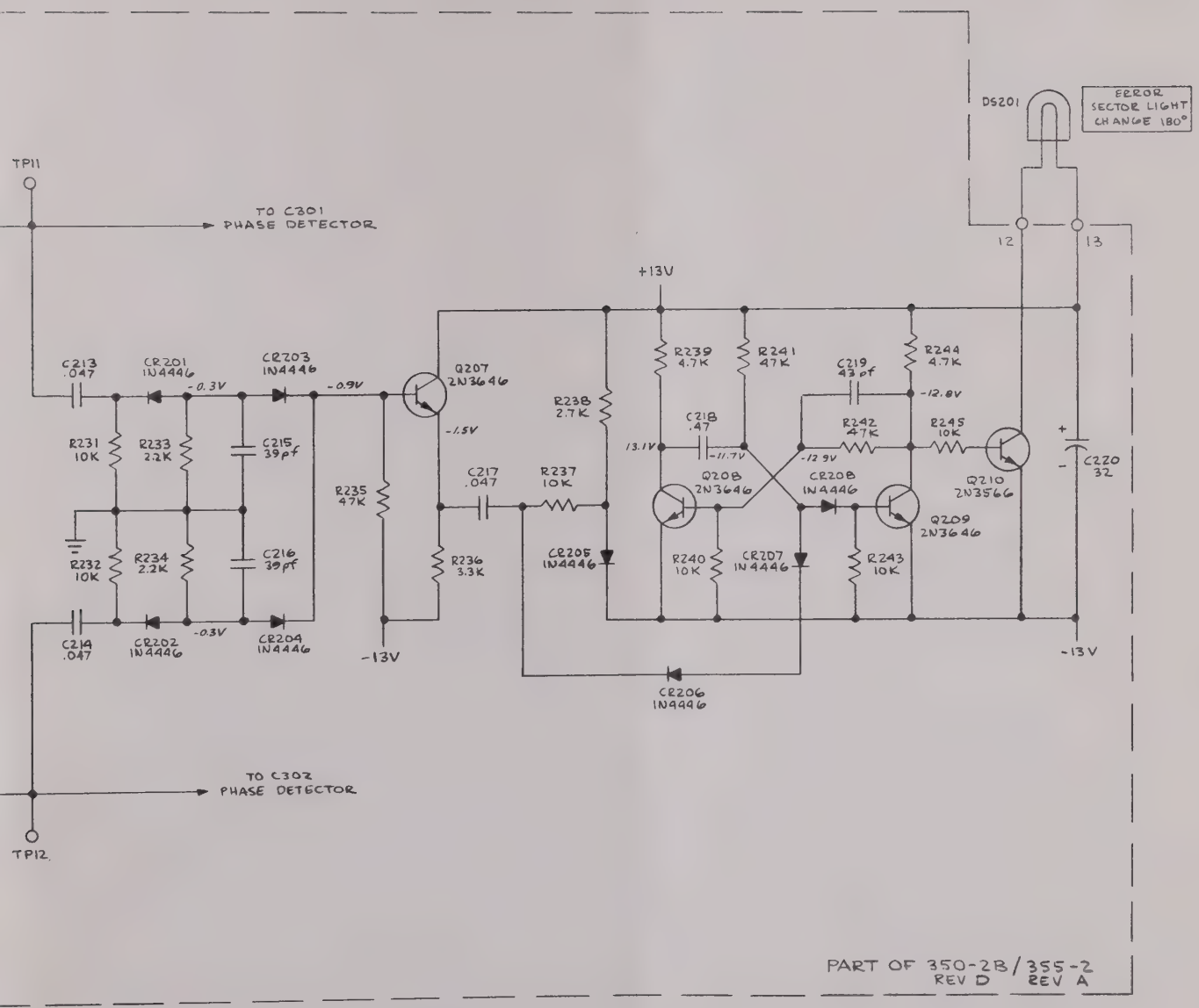
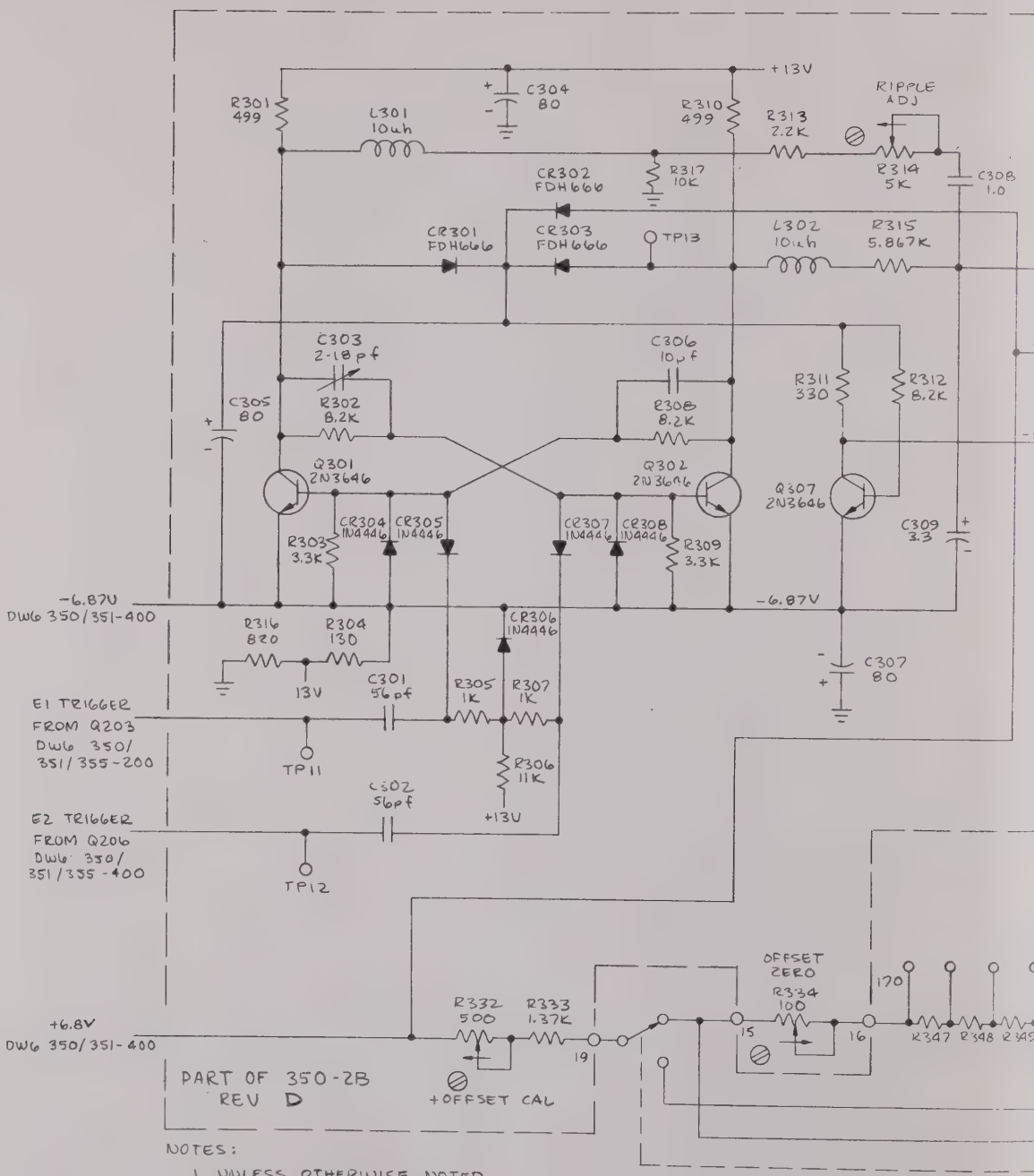


Figure 7-2. Trigger Circuits and Error Detector



NOTES:

1. UNLESS OTHERWISE NOTED.
   RESISTANCE IN OHMS.
   CAPACITANCE IN MICROFARADS.
   * FACTORY SELECTED VALUE.

2 VOLTAGES MEASURED WITH 1 VOLT rms INPUT TO EACH CHANNEL. S101 IN 200mV TO 400V POSITION. VOLTMETER WITH 10mΩ IMPEDANCE USED.

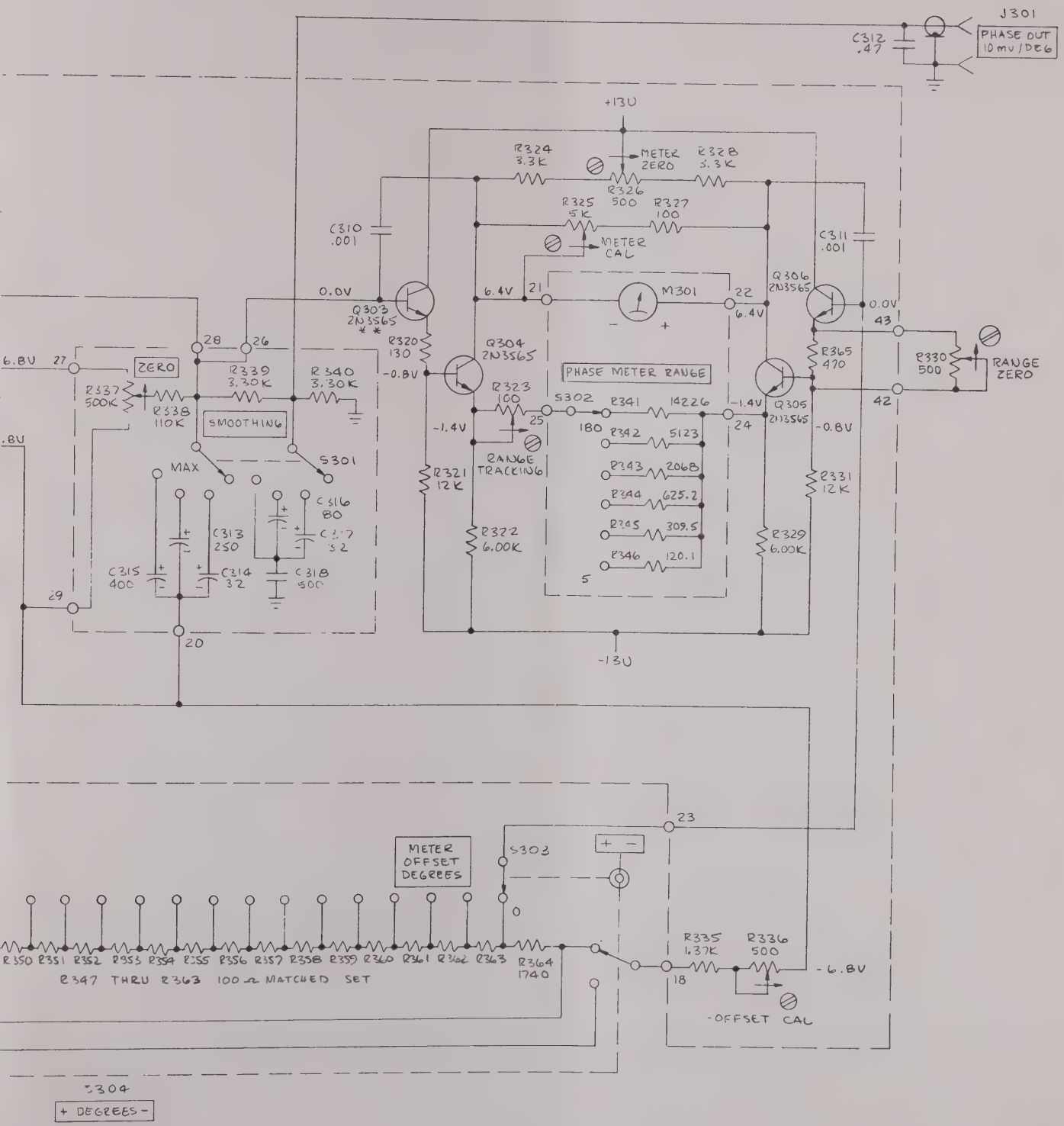
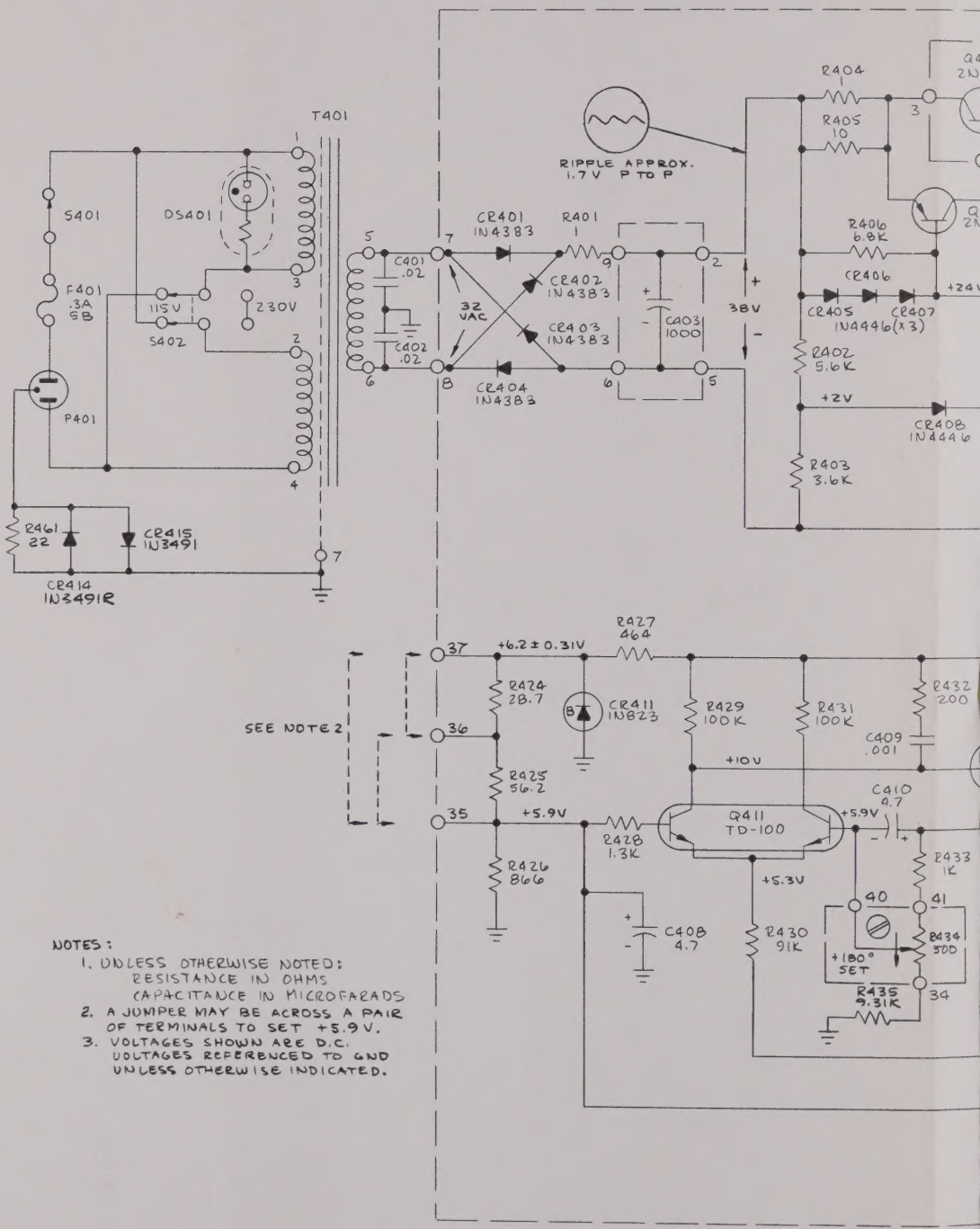


Figure 7-3. Phase Detector and Readout



NOTES:

1. UNLESS OTHERWISE NOTED:
   RESISTANCE IN OHMS
   CAPACITANCE IN MICROFARADS
2. A JUMPER MAY BE ACROSS A PAIR OF TERMINALS TO SET +5.9 V.
3. VOLTAGES SHOWN ARE D.C. VOLTAGES REFERENCED TO GND UNLESS OTHERWISE INDICATED.

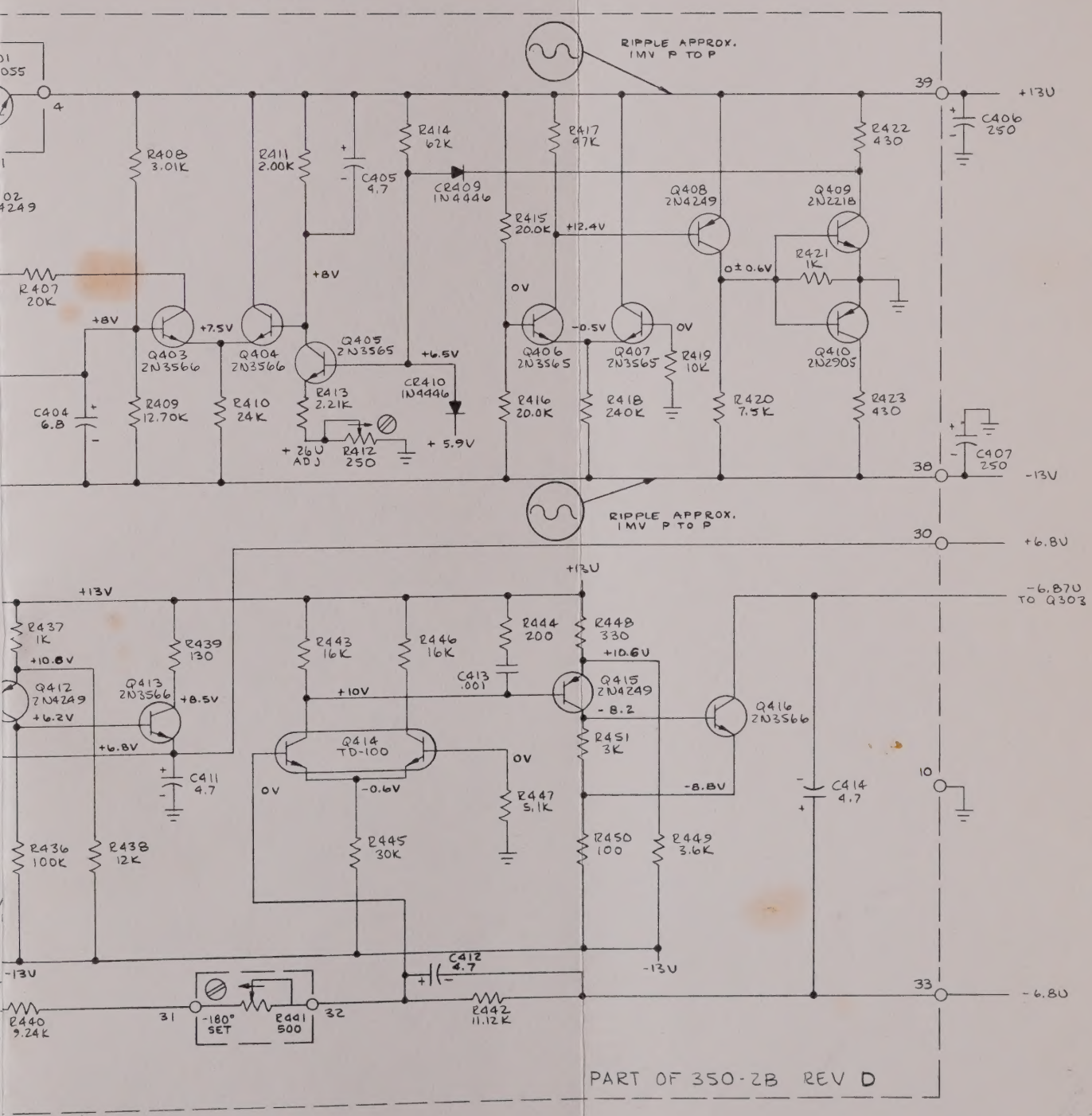


Figure 7-4. Power Supply and Regulator

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